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Equity and What Secondary Science Teachers Bring to the Classroom

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Equity and What Secondary Science Teachers

Bring to the Classroom

by

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For my family

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Equity and What Secondary Science Teachers

Bring to the Classroom

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The demographics of people working in science-based careers do not match the demographics of the larger society. In particular, people who self-identify as Hispanic are underrepresented among working scientists. One reason may be the influence of formal schooling and more specifically, the behaviors of teachers in secondary science classrooms. This study looks at the practices of eight secondary science teachers at two schools at which 62% of the enrolled students declare their ethnicity as Hispanic. All of the teachers have at least three years of experience. Through interviews with the teachers, classroom observation, and interviews with other faculty, this research elucidates typical behaviors and attitudes surrounding teaching science in these settings. In spite of having a deficit view of their students, they all express interest in and concern about the students they teach. Their characterizations of teaching practices and classroom behaviors do not incorporate strategies designed to promote content learning through culturally relevant curriculum. Instead, they use mainstream-situated approaches that develop science

content knowledge, vocabulary, procedures, and skills targeted toward high achievement on state and district standardized tests leading toward graduation or success in college. These approaches are consistent with a view of equity that increases the participation of underrepresented groups in science based careers in that it gives students the skills and knowledge they will need in order to successfully pursue these careers. Additionally, they behave in ways that are consistent with equitable strategies such as using inquiry based teaching, serving as role models, and providing a structured learning environment. This research informs the literature base for instructional systems designers by identifying what that teachers situated in culturally diverse classrooms bring to professional development programs targeted toward making secondary science teaching more equitable.

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CHAPTER ONE

INTRODUCTION

A shared attitude in American society is the idea that this is “the land of opportunity: a person’s ethnicity and/or sex should not be predicators of her career options.” However, this opportunity does not appear to extend to careers in science. Equity, as a minimum, would demand parity in science careers, but the underrepresentation of non-Asian minorities in science-based careers is well documented. Statistics show that science-based careers don’t exhibit the same ethnic ratios as the population at large (Clark, 1999). Opening the pathway to science-based careers to historically underrepresented populations is important for many reasons. First, in a democratic society, everyone should have equal access to lucrative careers including the same opportunities for mobility as all Americans (Banks, 1994). Second, participants from non-Westernized cultures offer different perspectives, agendas, and values that can enrich and enliven the pursuit of scientific knowledge, which is currently dominated by Western science. Third, the United States’ future as a technology leader depends on an educated population; there aren’t enough European Americans to fill all the projected jobs (Brown, 2001; Clark, 1999). For example, a multi-agency, public-private partnership titled Building Engineering and Science Talent (BEST) (Morella, 2002) was created to identify ways to attract women and minorities to science, engineering, and technology-based careers. Finally, in the seminal work, *Science for All Americans* (American Association for the Advancement of Science (AAAS), 1989), the AAAS advises that scientific literacy is essential for a high quality of life in a democratic society as citizens make decisions in the marketplace, the voting box, and the doctor's office (Mainschein, 1998) and thus the pathway should be available even to those who will not chose science as a career. In this sense, *equity* in science goes beyond the minimum of achieving parity in science career demographics to the goal of achieving universal access to science.

The role of science education in keeping this pathway open can be traced backwards to science experiences in the K12 curriculum. A critical indicator for choosing a major in college that would lead to a science-based career is taking elective science classes in high school (Farmer, Wardrop, & Rotella, 1999). However, Hispanic and African American students participate at lower rates in high school science classes and college science majors than their European American counterparts (Bianchini, Cavazos, & Helms, 2000). Two critical indicators for taking elective science classes in high school are interest in science-based careers and positive attitudes towards science (Joyce & Farenga, 1999; Eccles (1995) cited in Lynch, 2000; Neathery, 1997). Another factor that correlates with participation is achievement (Mattern & Schau, 2002), however, the direction of the correlation is unclear: greater achievement may lead to increased participation or increased participation may lead to greater achievement. For example, in middle school, females have the same level of achievement as males, but are already showing less interest in science-based careers and less positive attitudes towards science (DeBacker & Nelson, 2000; Francis & Greer, 1999). Since Hispanic, African American, and Native Americans lag behind Asian and European American students in science and math achievement in high school (Peng & Hill, 1994), they may be less likely to take the type of science classes that would lead to success in college-level science classes, prerequisite to pursuing a science-based career.

Equity and science education

National documents guiding science education and the preparation of teachers (e.g., National Science Education Standards (NSES), National Council for Accreditation of Teacher Education) emphasize the need for science instruction to be inquiry-based, science rich, and inclusive of all students. For example, one of the NSES standards (National Research Council (NRC), 1996) is to ensure equitable access by those who have traditionally not received encouragement and opportunity to pursue science (p. 221).

Yet the current reality is that most science instruction is inadequate for students who have historically not participated or persisted in science. Several studies have addressed this limited presentation of science in the classroom (e.g., Brickhouse & Bodner, 1992; Kawagley, Norris-Tull, & Norris-Tull, 1998; Lee & Fradd, 1998) and the low achievement and lack of participation in science classes by Hispanic American, African American, and Native American students (Jones, Mullis, Raizen, Weiss, & Weston, 1992; Lynch, 2000; National Center of Educational Statistics, 1994). Strategies suggested for making science classes more equitable include implementing culturally relevant curriculum (e.g., Banks, 1994; Ladson-Billings, 1995; Lee & Fradd, 1998; Pomeroy, 1994; Sutman, 1993), developing cultural literacy (e.g., Ladson-Billings, 2001; Ruiz, 1999; Valencia, 1997), identifying funds of knowledge (e.g., Hammond, 2001; Moll, Amanti, Neff, & Gonzalez, 1992; Seiler, 2001), believing your students are educable (e.g., Ladson-Billings, 1994, 2001; Pedersen, Faucher, & Eaton, 1978), enacting challenging curriculum (e.g., Clark, 1999; Ladson-Billings, 2002; Pomeroy, 1994), using inquiry based methods (e.g., Boone & Kahle, 1998; Kahle & Damnjanovic, 1994; Sherman & Weber, 1999), introducing classroom mentors and role models (e.g., Ascher, 1992; Brown, 2001; Clark, 1999; Marinez & Ortiz de Montellano, 1988; Mulkey & Ellis, 1990; Pomeroy, 1994), and promoting career education (e.g., Ascher, 1983; Brown, 2001; Mulkey & Ellis, 1990).

Equity and the science teacher

The demographics of classrooms are changing. For example, between 1986 and 1999, the percentage of White students enrolled in K-12 public schools decreased 12% while the percentage of Hispanic students increased 57% (National Center for Education Statistics (NCES), 2001). However, 69% of surveyed teachers feel unprepared to teach in culturally diverse classrooms (Futrell, Gomez, & Bedden, 2003). Science teachers need to be adequately prepared and supported if they are going to create learning environments that are conducive to all students.

In discussing the current and future state of equitable education, Lee (2003) calls for better teacher preparation programs and professional development opportunities to learn how to teach science to all students. She continues by identifying the need to find methods and content that meet students' needs (Lee, 2003). Teacher professional development at the preservice and inservice level should be designed to support the strategies identified in this section. In a review of the literature, Joyce, Showers, and Rolheiser-Bennett (1987) find that teachers have a limited range of strategies they use in the classroom. They assert teachers "expand that repertoire only when they are provided substantial and carefully designed training" (p. 22). Mundry (2003) proposes one aspect of this carefully designed training is discovery of the backgrounds, experiences, and assumptions about learning of the teachers for whom the program is being designed. Additionally, she says understanding the context in which the teachers teach is also critical. Her views are consistent with those advocated in the National Science Education Standards (National Research Council (NRC), 1996) for professional development which state, "The challenge of professional development for teachers of science is to create optimal collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers" (p. 58). Loucks-Horsley, Stiles, and Hewson (1996) advise that effective professional development must be enacted using the same methods advocated for classroom instruction of students including ascertaining prior knowledge of target teachers. In their book on designing professional development for science teachers, Loucks-Horsley et al. (1998)explain that including teachers as co-designers is a way to counteract the inadequate ways of traditional professional development. They assert “what learners know influences their learning” (p. 27), referring to teachers, the consumers of professional development as the learners.

Research questions

The purpose of this research is to inform the design of teacher development programs targeted toward equity, i.e., toward achieving science education that will maintain an open pathway toward scientific literacy and science careers for all students. Regardless of the learner, effective instructional systems should account for the prior knowledge learners bring to the educational situation (National Research Council (NRC), 2000a). In this case, the learners are classroom teachers who will be participants in these professional development programs. Through interviews and classroom observations, this project will reveal teachers’ knowledge and enactment of the strategies identified previously. Specifically, the questions that will be addressed in this research are:

1. How do secondary science teachers in culturally diverse classrooms characterize their teaching practices with respect to equity?
2. How are these characterizations manifested in their classroom practice?

CHAPTER TWO

LITERATURE REVIEW

Underrepresentation by groups in science-based careers must be addressed in part through education. Teachers are at the forefront of this change. For example, Fullan says, “Educational change depends on what teachers do and think—it’s as simple and as complex as that” (quoted in Nieto, 1999, p. 167). Nieto (1999) continues, “The role of teachers is a complicated matter because they are not solitary agents of change. But the inescapable truth that has emerged in this book is that teachers’ attitudes and behaviors can make an astonishing difference in student learning” (p. 167). Teaching practices contribute to the development of attitudes about subject matter (Norman, Ault, Bentz, & Meskimen, 2001). In addition, teaching practices affect learning outcomes (Stigler & Perry, 1999, April). This review of the literature presents both theoretical and research-based propositions about teachers’ attitudes and behaviors that make classrooms more equitable places with the purpose of increasing student engagement or achievement.

Implement culturally relevant curriculum

Curriculum may be defined as the conceptual content, topical content, and method of delivery of a course. One of the most important decisions a teacher makes concerns what and how to teach; choice of content is an important strategy (Sutman, 1993) for achieving equity. However, there is no consensus about what culturally relevant secondary science looks like. Ladson-Billings (1995) suggests that teachers use subjects from the students' home culture as "vehicles for learning" (p. 161). Pomeroy (1994) also finds the use of science content situated in the community culture a major component of multicultural science education in her review of literature. Banks (1994) advocates pedagogy that makes "maximum use of…local community resources," (p. 310).

Banks (1994) also suggests, however, that in secondary science, content is less a concern than the methods used to teach the subject. "Curriculum should reflect the cultural learning styles and characteristics of the students within the community," (p. 296). In other words, teachers should not teach in ways that conflict with, contradict, or devalue the students' home culture (Jegede & Aikenhead, 1999; Ladson-Billings, 1995, 2002; Lee & Fradd, 1998; Pomeroy, 1994). For example, self-directed, inquiry-based teaching does not represent culturally sensitive teaching for all populations (Banks, 1994; Lee & Fradd, 1998; NRC, 2000). Another oft-mentioned strategy for teaching culturally diverse learner is cooperative learning (Ascher, 1983, 1992; Brown, 2001; Ladson-Billings, 1995; Short & Spanos, 1989; Sutman, 1993). However, this strategy must be carefully monitored to ensure that it doesn't reinforce the inequitable power structure of the larger society (NRC, 2000). Similarly, Banks (1994) cautions that assessment strategies should reflect ethnic and cultural expressions (p. 310). In addition to selecting pedagogical strategies that reflect the cultural norms of students, teachers of culturally diverse learners should employ a variety of teaching strategies (Ascher, 1983; Clark, 1999; Lee & Fradd, 1998; Pomeroy, 1994).

One strategy that presumes universality is individualized instruction (Ascher, 1983, 1992; Clark, 1999) and the use of learning centers (Ascher, 1992). Rather than pacing instruction to the average student, individualized instruction requires teachers to evaluate the needs of individual students and teach to their strengths and weaknesses. Well-designed learning centers offer students choices about what they want to learn about; Mexican-American students respond positively to academic situations in which they are given choices (Tan, 2001), possibly because it helps them develop a better sense of self (Banks, 1994).

Another strategy some science textbook writers or teachers utilize is highlighting scientists from the culture of the students (Pomeroy, 1994), but this idea is not without controversy. Abdal Haqq (1994) suggests that materials that use "sidebar" multiculturalism or pick on "super heroes" of a particular culture do nothing to encourage students from historically underrepresented cultures. Ladson-Billings (2002) says to avoid the multicultural "festival"—super celebrations of heroes or holidays. However, Sutman (1993) believes that using examples of scientists from minority cultures is a positive practice because it provides historical role models for students. Using examples (of scientists or discoveries) from cultural background of students sends the message “my forbearers did this, I can to,” (Marinez & Ortiz de Montellano, 1988). One way to find historical examples is to expand the notion of “what is science” (Marinez & Ortiz de Montellano, 1988). For example, Marinez and Ortiz de Montellano (1988) suggest teaching about Mayan mathematics and refer the reader to a several sources for lesson plans on Mayan mathematics and timekeeping. Another suggestion Marinez and Ortiz de Montellano make is looking at native plants or traditional dying techniques. Ironically, for many of these topics, they go on to suggest lesson plans that follow the tradition of Western scientific methods and thought exclusively, such as using modern conceptions of geology to propose models for the underlying strata. Finally, multicultural materials should recognize that “Hispanic” or “Hispanic” is not a culture. There are many groups, such as Puerto Ricans or Cubans, and subgroups, such as first-generation Mexicans or second-generation, middle class Mexicans, which would identify themselves as Hispanic or Hispanic but could have very different cultures.

<u>Develop cultural literacy</u>

In order to implement culturally relevant curriculum, teachers must know the culture of the students. Unfortunately, deficit thinking about students’ culture (Valencia, 1997) is a paradigm that currently prevails in education, exhibited, for example, in such language as “at risk”. Ladson-Billings (2001) acknowledges the prevalence of this model; she fears "'Helping the less fortunate' can become a lens through which teachers see their role" (p. 83). She explains that students' cultures must be reinforced at school in order for students to develop into responsible, self-sufficient adult citizens. In discussing the devaluing of students' extracurricular lives she warns, "Such an approach to teaching diverse groups of students renders their culture irrelevant. There is nothing to be learned, let alone built upon and developed" (p. 83). She stresses that increasing the home-cultural competence of students supports learning outcomes and future success in the larger society (Ladson-Billings, 1994). Valenzuela's work (1999) reinforces this assertion by correlating assimilationist schooling with negative outcomes for Mexican American students.

The counter to deficit thinking is awareness, acknowledgement, and reinforcement of students' home cultures. Ladson-Billings (1994) explains that equitable teachers "use cultural referents to impart knowledge, skills and attitudes" (p. 18). She asserts, "They help students make connections between their local, national, racial, cultural, and global identities" (p. 25). She continues, "Rather than expecting students to demonstrate prior knowledge and skills they help students develop that knowledge by building bridges and scaffolding for learning" (p. 25), the antithesis of deficit thinking. Ruiz (1999) explains that as teachers become students of their students, the teachers see the students' culture as valuable, informative, and part of the curriculum.

In order to understand the norms, knowledge, and cultural literacy students bring to the classroom, teachers must spend time in the students' community (Banks

& Banks, 1995; Ladson-Billings, 2002). As they acknowledge and validate the home culture, students are less likely to drop out of school and more likely to be successful (Tan, 2001). Furthermore, science teachers who understand the amount of congruence, or lack of it, between the school and home worldviews are better able to assist students as they negotiate traveling between these two important worlds (Jegede & Aikenhead, 1999).

In becoming culturally literate, teachers must discover the world view, values, and dreams for the future (Román, 1999). For example, many teachers view Hispanic cultures as anti-scientific, filled with magic and superstition rather than a tradition of scientific thought (Marinez & Ortiz de Montellano, 1988); rather than making assumptions, teachers must develop literacy about the true cultural background and experiences of their students. In an oral history class, Benmayor (2002) found that first-generation college students of Mexican origin drew upon family encouragement and cultural resources when deciding to apply to college in the face of "discriminatory treatment" (p. 101) from high school teachers and counselors. She was surprised that acquiring a college education was a dream of the parents of her students, even though none of these parents had been to college.

Although knowledge of students' culture seems a logical necessity in order to teach culturally relevant pedagogy, only the Tan (2001) article presents classroom data. The other writers in this section offer a variety of anecdotes to support their assertions but none of them present a systematic study of student outcomes.

Developing cultural literacy requires teachers to include the notion of "teacher as learner" in their conception of identity. In addition to learning about the home lives of their students, Gay asserts that teachers should also learn about "ethnic and cultural groups' histories and heritages […] and interactional styles to bridge the gap between the cultural values and behavioral codes of themselves and their students" (quoted in Cristol, 2001, p. 163). Teachers should learn about their teaching from their students' classroom actions. Ladson-Billings (2001) shares a story of Carter, a 3rd grade teacher, who was frustrated by his students' unwillingness to write using the traditional curriculum. Aware of their interest in music, he got them to act out a song that had a story told by musical instruments. Through a series of follow-up activities, he eventually got them interested in writing. Ladson-Billings (2001) comments,

> […] the place for improving student performance begins with the teacher. Although it is clear that teachers cannot carry the entire burden for students' academic performance, it should be equally clear that they shoulder some of it. Excellent teachers who are faced with student failure are quick to ask themselves, "What am I doing that contributes to this failure?" (p. 21).

In addition to learning from their students, incorporating the concept of "teacher as learner" into their identity can help teachers identify more with their students. Ruiz (1999) found that in his attempts to learn Spanish as an adult, he started exhibiting many of the behaviors he saw in his students, such as expressions of tiredness, disengagement in the language classroom, and feelings of wanting to quit. He said that as teachers become better learners, they undergo a change from seeing students as objects to deposit knowledge into to seeing students as vehicles for their own learning. He concludes by saying, rather than merely learning about them, “teachers need to learn what can help their students learn” (p. 143). Consequently, equitable teaching can’t be reduced to strategies.

Identify funds of knowledge

An example of practical implementation of culturally relevant curriculum through developing cultural literacy is given in the “funds of knowledge” approach pioneered at the University of Arizona (e.g., González, Andrade, Civil, & Moll, 2001; González et al., 1993; Hammond, 2001; Moll et al., 1992; Seiler, 2001). “Funds of knowledge” means the cultural artifacts and bodies of knowledge held by a community. The hallmark of this approach is having teachers make visits to the homes of their students. The purpose of these visits is for teachers to learn about the home lives and family situations of their students through interviewing those present in the home.

González (1993; 1995) describes her work with a group of elementary school teachers who did this type of anthropological research on the family of one of their students. Through these visits, the teachers discovered that many of the families gave up a relatively good life in Mexico in order to provide better educational opportunities for their children in the United States. The teachers’ views changed from a deficit model of students’ backgrounds to one rich in experience and support from the family. Although González said that discovering students' funds of knowledge "could form the basis for curriculum units in science, math, language arts, and other subjects" (p. 11), she did not give any examples of science units that teachers created from these funds of knowledge. She acknowledged that teachers found using this knowledge about students' home lives a difficult and "intricate process" (p. 18).

Barton and Osborne (1995) describe experiences in making a high school chemistry class more accessible to Mexican-American students. After a lecture on the ideal gas law, students discussed how they could understand the law using experiences from their home life. These included a whoopee cushion, automobile tires, and cooking. After a traditional lab, students were asked to connect their experimental observations with previously discussed home experiences.

McIntyre, Roseberry, and González (2001) offer more examples of how teachers have used students' funds of knowledge to create meaningful and engaging curriculum. Sharon, an 8th grade teacher at a Zuni middle school used the concept of traditions, drawing on students' Zuni culture and having them compare it to Jewish culture, in a unit on writing. Through post-unit student evaluations, Sharon discovered the unit was well received. Vivette, a 3rd grade teacher of primarily African American students in California, used her insider's knowledge of African American culture in science. She began a unit asking students if they've heard the phrase, "one rotten apple spoils the whole bunch." Over the course of a few weeks, students observed what happened in a basket of apples with a rotten one placed in the center. Students studied well known and lesser-known African American scientists. The science club named an outdoor garden after George Washington Carver. Vivette uses “call and response, a highly interactive African American communicative discourse pattern” (p. 33) in her instruction. McIntyre, Roseberry, and González (2001) include additional chapters on an elementary school teacher who used a parent’s expertise with gardening in developing a school garden. The teacher describes a math project that resulted from the collaboration. Students were able to transfer the math concepts they learned from gardening to new situations. A middle school teacher had her students use their native drums in learning concepts about sound waves and reinterpreting native terms for the quality of sound. A preschool teacher taught students about life science by involving them in asking questions in order to determine the content of the curriculum. An elementary teacher used a multiple perspective approach for teaching history, including not only examples from the African American culture of her students, but also several Native American cultures. A middle school math teacher helped his Mexican-American students feel less disenfranchised by engaging them in a “build your dream house” project that taught principles of algebra, geometry, probability and statistics, and arithmetic. Parents and other community members were invited to the final presentations.

Using a synthesis of anthropological and ethnographic data, Vélez-Ibáñez and Greenberg (1992) suggest several reforms that follow from understanding the funds of knowledge of Mexican American students living near the border. For example, they assert cooperative learning paradigms more closely mirror the social interaction patterns in students' home culture. Additionally, they claim relationships in the learning environment should include more frequent and "thicker" interactions, reflecting the social density children are accustomed to. Finally, teachers need to be trained how to incorporate students' funds of knowledge into the curriculum.

Lee (1992) postulated that the discursive pattern of signifying could help African American students interpret irony and metaphor in fiction. She created an intervention in which students examined signifying dialogues and had to justify their characterization of each speaker's meaning. In a controlled experiment of 95 high school students, she found the experimental group had pre-post gains 3 times those of students in the control group who were taught using the standard curriculum.

An important result of having teachers conduct anthropological research on their students is the transformation of teachers' conceptions about students from a deficit model to an awareness of the rich experiences, values, dreams, and knowledge that fill their students' lives (González et al., 2001; González et al., 1993, 1995; McIntyre et al., 2001; Moll et al., 1992; Román, 1999; Ruiz, 1999). The intention of identifying funds of knowledge is that teachers will capitalize on students' culture in the creation of curriculum (Ladson-Billings, 1994; Lee, 1992; Patterson & Baldwin, 2001; Román, 1999) reinforcing connections between school knowledge and home life.

<u>Believe your students are educable</u>

Ladson-Billings (2001) says a principal characteristic of good teachers of culturally diverse students is that they “presume that all students are capable of being educated” (p. 74). This viewpoint arose from an earlier study she conducted about characteristics of successful teachers of African American children. She solicited names of equitable teachers from parents and administrators in a school district. Of the nine teachers appearing on both lists, she did an in-depth, three-year study of eight. One theme she found was that these teachers believe that all of their students can succeed rather than that failure is inevitable for some (Ladson-Billings, 1994).

This finding about the efficacy of teacher beliefs about students’ ability to learn is supported in the research of Pedersen, Faucher, and Eaton (1978). They did a two-part study about the long-term effects teachers have on student outcomes. The first part of the study involved a historical analysis of students’ IQ using students’ permanent records. These students attended a school in one of the poorest areas of a large Northeastern city. They found that more of Miss A’s students exhibited an IQ increase between first and sixth grade than the students of other first grade teachers at the same school. The second part of the study involved finding these same students as adults and characterizing their achieved life status. 64% of Miss A’s students had achieved high status compared to 31% of Miss B’s and 10% of Miss C’s. The remaining 36% of Miss A’s students achieved the middle status. None of her students were in the low status compared to 31% of Miss B’s and 45% of Miss C’s. Pedersen, Faucher, and Eaton suggest that Miss A’s belief in the ability of her students explains this outcome.

Ferguson (1998) summarizes several studies about the effect of teachers’ attitudes or expectations on students. He cites studies that detail that students believe teachers favor students they perceive as smart and that the role white teachers play "in determining how students feel about their positions in the achievement hierarchy" (p. 341) is more central for black students than for white ones. In contrast, Murrell and Foster (2003) caution that focusing on teacher beliefs about equity eclipses the more important characteristic of disposition. They posit that teacher education programs should develop and reinforce the propensity to behave in equitable manners.

Enact challenging curriculum

Culturally relevant curriculum should not be a watered-down curriculum. The same standards should guide the instruction of all students (Rivera & LaCelle-Peterson, 1993). Teachers should maintain high expectations and teach scientifically meaningful and relevant content regardless of the cultural diversity in their classroom (Clark, 1999; Ladson-Billings, 2002; National Science Board Commission on Precollege Education in Mathematics, 1983; Pomeroy, 1994). Teachers should not assume that because students lack English language proficiency, that their background knowledge and science process skills are likewise deficient; even English language learners should receive the same content and be subject to the same expectations as more proficient speakers of English (Sutman, 1993). Furthermore, multicultural education should develop the knowledge and decision-making skills necessary for full political participation in adulthood; in order to be equal participants in the society, students from non-mainstream cultures must receive equal education (Banks, 1994), including the knowledge-base accepted by the mainstream. Brickhouse (1994) posits that “teachers should continue teaching students the facts and theories of science, ways of solving scientific problems and how science operates within a society” (p. 410) as an essential strategy for increasing participation in science of underrepresented groups.

Brickhouse (1994) advocates basing the science curriculum on the idea of students as producers of knowledge in establishing “joint understandings” that “legitimate students’ cultures and understandings of the natural world” in a collaborative rather than intellectually competitive environment (p. 409). However, she warns that teaching the “scientific canon” is essential in the science classroom so that students will “develop the competence needed to understand socio-scientific problems” (p. 409). Even as he advocates that teachers and students learn about students’ cultures together, Ruiz (1999) warns that “does not imply that students’ and teachers’ knowledge have equal power and status in society” (p. 142). He maintains, “Teachers have the responsibility to need to teach students the cultural capital that they need to help them negotiate society” (p. 142). He continues, “Teachers have a grave responsibility to prepare students to become effective and critical participants in the world” (p. 143).

Use inquiry-based methods

According to the reforms of the 1990s, science should be taught primarily through inquiry-based instruction (e.g., American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996, 2000b). Weinburgh (2003) found mixed results from a control-group study of 5th graders using of inquiry-based science kits. Although the students generally showed increasing positive attitudes towards science after the intervention, they were less positive about the value of science to society.

Sherman and Weber (1999) report about a professional development project in a "special needs district" in which elementary and middle school teachers created a thematic learning unit which required the use of technology to solve a problem. Part of the professional development included instruction on equitable strategies. Researchers found teachers were surprised students could perform higher-level cognitive tasks than they previously thought, leading to more engaging and meaningful instruction. Teachers noted students they had previously characterized as disruptive or problem students became assets in the more democratic and participatory classroom. Observational data indicated no differences between male and female participation.

Kahle and Damnjanovic (1994) did a similar professional development intervention with 4th and 5th grade teachers in an urban school district. Teachers were taught how to use inquiry-based materials immediately prior to classroom implementation. Pre-post analysis of students' attitudes, confidence, and ease about science found that girls anticipated enjoyment of electricity topics increased, especially for African American girls.

Boone and Kahle (1998) analyzed a systemic initiative program to introduce inquiry-based teaching to teachers across the state of Ohio. Disaggregating student survey data by gender and race, they found that girls in inquiry-based classes reported greater access to instruction advocated in national science education documents than girls in non-inquiry based classes. Similar results were found for African American students in inquiry-based classes versus non-inquiry based classes. Additionally, African American students in these inquiry-based classes also perceived that their friends participated in extracurricular science activities more than African American students in the non-inquiry-based classes.

Introduce classroom mentors and role models

An important step in opening the pipeline to students from cultures that are historically underrepresented in science is changing adult identity expectations. Bringing practicing scientists who share students' cultural background into the classroom sends the message that "someone like me can be a scientist" (Ascher, 1992; Brown, 2001; Clark, 1999; Marinez & Ortiz de Montellano, 1988; Mulkey & Ellis, 1990; Pomeroy, 1994). Brown (2001) describes a program in El Paso which sponsored classroom outreach by women employed in technology-based careers. By the end of 10 years, the number of women taking technology-related courses at the local community college had more than doubled. Promoting formal and informal interactions with mentors and classroom role models expands the image of a scientist from a "white man in a lab coat," leaving students from all cultures more open to considering science as a possible career option (Ascher, 1983; Brown, 2001).

Riesz, McNabb, and Stephen (1997) found similar results in their longitudinal study of high school students. Over a two-and-a-half-year period, 262 students, 130 of which were female, were introduced to 40 female and minority scientists, physicians, architects, and engineers, during their science classes. The visits were timed to coordinate with concept introduction and the mentors helped generate lab activities that incorporated their real-world work into the science curriculum. The students were followed throughout their four years in high school. Although the cohort started 9^{th} grade exhibiting gender differences in attitudes towards science, these differences had disappeared by the time they reached 12^{th} grade. Additional research also showed no gender differences in number of science credits earned although there were significant gender differences in a baseline cohort at the same school that had not had the treatment.

Promote career education

In addition to teaching content, teachers should also create student interest in science-based careers. One way teachers can do this is by linking the subject to specific careers (Ascher, 1983; Mulkey & Ellis, 1990). Students tend to study subjects that they think they might pursue or use in a future career (Brown, 2001; Clark, 1999). Consequently, teachers should present these careers as open to anyone

(Clark, 1999), through highlighting historic figures in science from the same cultural background as the students (Marinez & Ortiz de Montellano, 1988; Pomeroy, 1994), or bringing in practicing scientists as guest speakers, mentors, or role models (Ascher, 1992; Brown, 2001; Clark, 1999; Marinez & Ortiz de Montellano, 1988; Pomeroy, 1994).

Clark (1999) believes that early involvement in science is the gateway to a lucrative and fulfilling career. Classroom teachers can ask middle school counselors to encourage all students to take more science and technology classes in preparation for high school science courses (Brown, 2001; Clark, 1999). Students must not only be intellectually aware of a particular career but must also feel emotionally connected to it because of its personal relevance to their lives in order for it to become a viable career alternative (Brown, 2001; Clark, 1999). Teachers' knowledge of students' cultures (Banks & Banks, 1995; Ladson-Billings, 2002; Lee & Fradd, 1998) facilitates promotion of science-based careers as they help students find links between their community and future professions.

<u>Utilize "best-practice" language strategies</u>

English language learners at the secondary level are in a difficult position with respect to science instruction. If they are placed in an English as a Second Language (ESL) classroom, their instructor is likely trained in language acquisition but not science. "In these settings, class work generally focuses on learning science vocabulary" (Buxton, 1998, p. 343). Consequently, their exposure to high quality, challenging science curriculum would be limited. However, their placement in the normal science classes with a lecture format may also be problematic in that the level of English maybe too advanced for them to effectively learn the science content (Buxton, 1998).

In the given political climate, language is probably one of the most sensitive issues with regards to education. English-only movements have spread from California throughout the country. Oddly, this push to establish an “official” language is a relatively recent trend in the United States. The framers of the constitution refused to declare a national language because they felt it was undemocratic. Many public schools required students to learn more than one language and literacy in at least two languages was required for many doctoral degrees. However, in order to instruct in a way that widens the pipeline to careers in science, teachers must understand several issues surrounding the topic of language.

First, every teacher, regardless of subject, teaches language (Banks, 1994; Sutman, 1993). Reading and understanding English is critical for higher achievement in school (Creswell, 1983). Teachers must discount the myth that students “pick-up” the language they need and that immersion or exposure is all they need to learn English (Rivera & LaCelle-Peterson, 1993). Additionally, first language competence is essential for developing the linguistic ability necessary to master advanced reasoning in English (Dawe, 1983). Science instruction must support the development of communication skills through listening, reading, writing, and speaking. Additionally, dialogic patterns of argumentation, evaluation, and analysis are not present in all cultures—different dialogic patterns may inhibit the development of scientific discourse and reasoning among non-Western students. Short and Spanos (1989) suggest that science and language arts teachers collaborate in curriculum development of science content in order to design lessons and units that enhance the development of linguistic skill. They also recommend that preservice science teachers receive some language arts training. Finally, Banks (1994) proposes that in the movement to eradicate “English ethnocentrism,” not only should educational materials be multilingual but all students should receive second language instruction (p. 260).

Second, students come to school with different linguistic competencies. Cultural differences may limit the ability to correctly interpret text-based readings or problems. Students that can define “all of the words” may still have communication issues due to incongruence between the dialogic patterns of the home and school culture. Even slight miscommunications, if they are continual and persistent, can lead students to feel alienated and discontented, possibly leading to emotional, if not physical withdrawal from school (Banks, 1994). Mestre (1989) found that Hispanic and European American students tend to make the same types of mistakes when solving word problems, but that Hispanic students made them with a far greater frequency and were less able to eventually self-correct. He advises teachers to get students to actively confront discrepancies in their proposed solution through questions, eliciting qualitative, quantitative and conceptual understanding. As teachers push students to generate solutions that are consistent with data or observations they are also advancing students linguistic competence. In a similar vein, Sutman (1993) advocates inquiry instruction because it enhances the development of language as students are forced to formulate questions, discuss and develop data collection procedures, develop and refine conclusions, and communicate with peers and the teacher. He also encourages heterogeneous groups of language-proficiency students using a cooperative learning pedagogy.

Finally, teachers should allow various linguistic modes to present knowledge(Rivera & LaCelle-Peterson, 1993) including talks, posters, and presentations. Alternative assessments allow students who lack linguistic confidence to show what they know in a manner in which they feel most comfortable (Sutman, 1993). This ability to choose assignments positively influences Mexican-American students' feelings about the classroom environment (Tan, 2001).

Miscellaneous strategies

In order to advance the development of cultural role identities that include science as a career choice, parents should be encouraged to be actively involved in the science classroom and education of their students (Clark, 1999; Sutman, 1993). Additionally, teachers can establish educational opportunities, such as parent nights, with the primary purpose of communicating the message that all students can learn science and that all students should take math and science every year (Clark, 1999). The joint messages of teachers, guidance counselors, and parents raise student awareness about career choices in science and reinforce a cultural redefinition of role identity (Marinez & Ortiz de Montellano, 1988).

Ascher (1992) recommends avoiding the use of standardized tests because they imply that ability is static. Also, they only record what students know but not where they need help. Finally, she says they lead to hierarchical sorting of students, which can negatively impact self-esteem. However, she and others advocate using diagnostic tests (Ascher, 1983; Short & Spanos, 1989; Sutman, 1993) in order to plan remediative teaching as necessary. Further, Sutman (1993) warns that English language learners are often put in low-ability classes regardless of their actual abilities.

Incorporating technology as part of content (Ascher, 1983; Brown, 2001) ensures that all students have equal access to skills essential in today's society, regardless of their socioeconomic status or what their parents can or do provide at home.

Teachers should make sure the classroom is a physically pleasing place to be (Banks & Banks, 1995; Ladson-Billings, 2002) that welcomes all students. For example, classrooms in which the desks are arranged in rows may convey the idea that all students can learn the same thing in the same way at the same place. Arranging the room in groups or around learning centers sends the message that students can learn in a way that is appropriate for them (Banks & Banks, 1995).

Another strategy that promotes learning is the use of games for content instruction (Ascher, 1983; Brown, 2001). Because games are viewed as play, they involve students in problem solving in a relaxed atmosphere. In other words, students develop skills in a low-risk situation.

Synthesis

The strategies identified for making teaching more equitable have two aspects. The first aspect concerns presenting the subject matter content and the second concerns teaching behaviors and the relationships teachers build with students. Implementing culturally relevant curriculum includes both aspects: teachers should situate concepts in the context of students' communities and teach these concepts through methods that "reflect cultural learning styles" (Banks, 1994, p. 296). Developing culturally literacy is more closely linked with the second aspect of equitable strategies as it involves learning about students' home culture and helping them to develop an identity situated in that culture. The "funds of knowledge" strategy includes both aspects of equitable strategies: in the process of building relationships with students and their families, teachers discover home knowledge that provide the context for teaching subject matter content. Believing your students are educable would be displayed in building relationships with students and would therefore fall under the second aspect of equitable strategies. However, teachers would also have to believe their students are capable of learning science in order to do a conscientious job of thoroughly presenting the subject matter. Therefore, believing your students are educable also concerns the first aspect of equitable strategies. Enacting challenging curriculum clearly concerns the first aspect as does inquiry based learning, since inquiry is not only an effective pedagogical strategy for all subjects but also teaches students about the nature of science. Although overlapping with the first aspect, introducing classroom mentors and role models and promoting career education deals more with teaching behaviors. “Best-practice” language strategies, involving parents, incorporating technology, assessment choices, and classroom environment all fall under the second aspect of equitable strategies.

Distinguishing these two aspects is important because curriculum is composed of two parts: content and the teaching behaviors through which students develop content knowledge. High school content is divided into subject areas such as social studies, language arts, math and science. These subject areas are then divided into disciplines. For example, science is comprised of the disciplines of biology, chemistry, and physics, in addition to many others. Within each discipline there is a substantive structure (Gardner, 1972) which “is the network of related theories and laws and concepts that individual researchers bring to bear when they set out to solve problems in their disciplines” (p. 27). The syntactical structure (Gardner, 1972) defines the way new knowledge is generated, that is, the thought processes leading to and methods of validating that new knowledge. Thus, the substantive structure of biology would include statements such as “genetic mutations are random” and “$p^2 + 2pq + q^2 = 1$ for large, stable, randomly mating populations”. The syntactical structure of biology would include DNA sampling, feature comparison of organisms, and study of atmospheric history revealed in the geologic record. Science teachers are charged with teaching both the substantive and the syntactical structure of their disciplines that together comprise content.

Teachers hold authority and responsibility for the curriculum, that is, they have the power to make instructional decisions about the content of the discipline they are hired to teach and the manner in which they choose to teach it. Content can be further subdivided into underlying science concepts and the topic through which those concepts are taught. For example, in chemistry, one underlying concept is the Kinetic Molecular Theory. What the researchers cited in this chapter imply is that culturally relevant topics and home life experiences should form the vehicle for teaching the behavior of gases. Taking account this divided nature of content, curriculum can be seen to have three aspects: the concept, the topic used to teach the concept (context), and the method by which students are given the opportunity to learn the concept. However, rather than seeing these as three separate areas, two of which teachers have choice about, based on previous experiences learning science, it is likely that they see the concept, the topic used to teach the concept, and the method as a monolithic structure.

In addition to the content-method tension, there is another dual aspect to these strategies: there is sometimes disagreement about whether or not particular strategies in fact promote equity. For example, Banks (1994), Lee and Fradd (1998) and the NRC (2000) caution that inquiry based strategies may not be effective for all groups of students. However, Sherman and Weber (1999), Kahle and Damnjanovic (1994), and Boone and Kahle (1998) found inquiry based strategies increased achievement for groups typically underrepresented in science. Since the purpose of this research is to discover ways to increase the participation of groups who have not historically participated in science careers, the application of these strategies must be viewed through the lens of improving attitudes about science and increasing achievement, two indicators at the secondary level that have been shown to lead students along the pipeline to science based careers (Joyce & Farenga, 1999; Eccles (1995) cited in Lynch, 2000; Neathery, 1997).

Summary

The ideas presented in this review of the literature comprise the classroom strategies most commonly suggested to address the persistent problem of underrepresentation by women and non-Asian minorities in science-based careers. It is important to note that very few of these strategies are supported by student achievement data or longitudinal studies of students' persistence in science classes throughout their tenure in the educational system. The vast majority of data presented in these articles is anecdotal or based on teachers' reflective journals.

Additionally, very few of these articles on equitable strategies address science at the secondary level. For example, research on "funds of knowledge" involved all subjects at the elementary level but only language arts and mathematics at the middle school or secondary level. Articles that involved secondary science, such as Barton's (1995) discussion of students in her chemistry class, involved no systematic collection of data to support efficacy of culturally responsive curriculum.

Additionally, the connection to students' lives was tangential rather than central to the instruction about the ideal gas law. Ladson-Billings study (1994) was an in-depth longitudinal study but offered no advice specific to teaching science. Only two of the strategies, use of role models and inquiry-based instruction, occurred in a science context and were supported with systematic research. What this literature review reveals is that secondary teachers lack a research-based model to follow to make their science teaching more equitable.

CHAPTER THREE

RESEARCH METHODOLOGY

Theoretical frame

The theoretical frame provides the lens through which the research questions are being studied (Kerlin, 2003). It details the assumptions about how and why things occur or are the way they are (Teresa McCarty, lecture notes, January 28, 2002). The lens for this study arises from my perspective as a future teacher educator. I believe that teacher education programs for preservice and inservice teachers have the power to affect teachers' enactment of and response to classroom events. Classroom events are well studied but controversially characterized phenomena. Even a simple assessment like, "The role of the science educator is to mediate scientific knowledge for learners," (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 6) is open to debate. Therefore, I feel that I can most clearly describe my view of classroom events through the use of an analogy. I will present my framework comprising assumptions about classroom events through the analogy of an aquifer (see Figure 1). An aquifer is a "geological formation containing or conducting groundwater" (*Webster's new universal unabridged dictionary*, 1996, p.

105). For this framework, the analogy is that of an unconfined aquifer, or one in which water flows due to gravity and not built-up pressure (see Figure 1).

By definition, an unconfined aquifer has water flowing it in. The water existing in an aquifer is called groundwater. Water is added to the aquifer via the geological formations above it from either atmospheric water (precipitation) or surface water (runoff, lakes, streams, rivers, oceans). Collectively, these two types of water are termed meteoric water. As meteoric water percolates down through the geology of the subsurface, it undergoes possible transformations due to the physical and chemical properties of the subsurface formations. First, it can be absorbed into the geologic formation and diminish in quantity. For example, a subsurface with clay tends to hold water rather than allow it to continue a downward descent, diminishing the maximum possible amount of water that could feed the aquifer. Second, the quality of the water may change as the geology adsorbs chemicals from the water or dissolves and releases them into the water. For example, the soil may adsorb organic solvents such as trichloroethylene from the percolating water or carbonate minerals may dissolve into the water, increasing its acidity. After one or both of these processes, meteoric water reaches the aquifer and mixes with the groundwater flowing through it, most likely modifying its chemical quality. This modification of the groundwater could increase or decrease the concentration of chemicals in it depending on the relative compositions of the meteoric water and the groundwater. Additionally, the groundwater already flowing through the aquifer may affect the geological formation, depending on the characteristics of the groundwater and the

Figure 3.1: Model of an aquifer

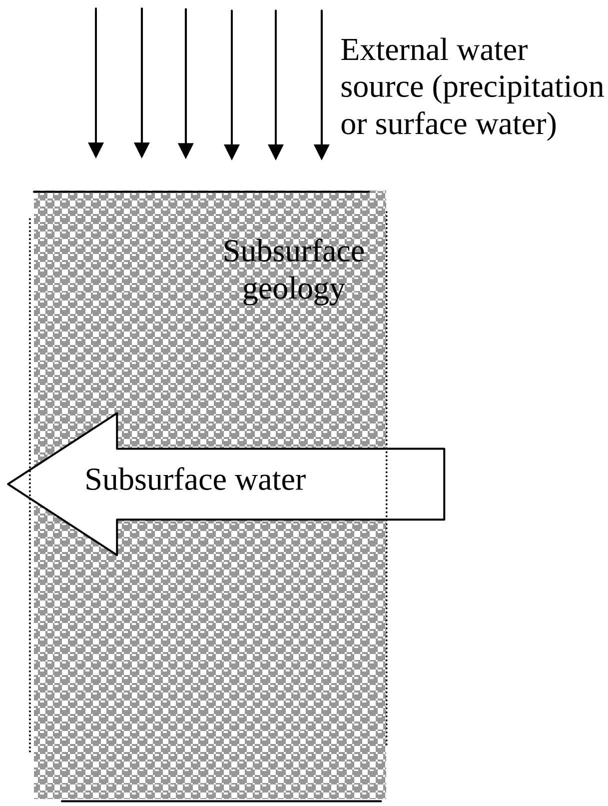
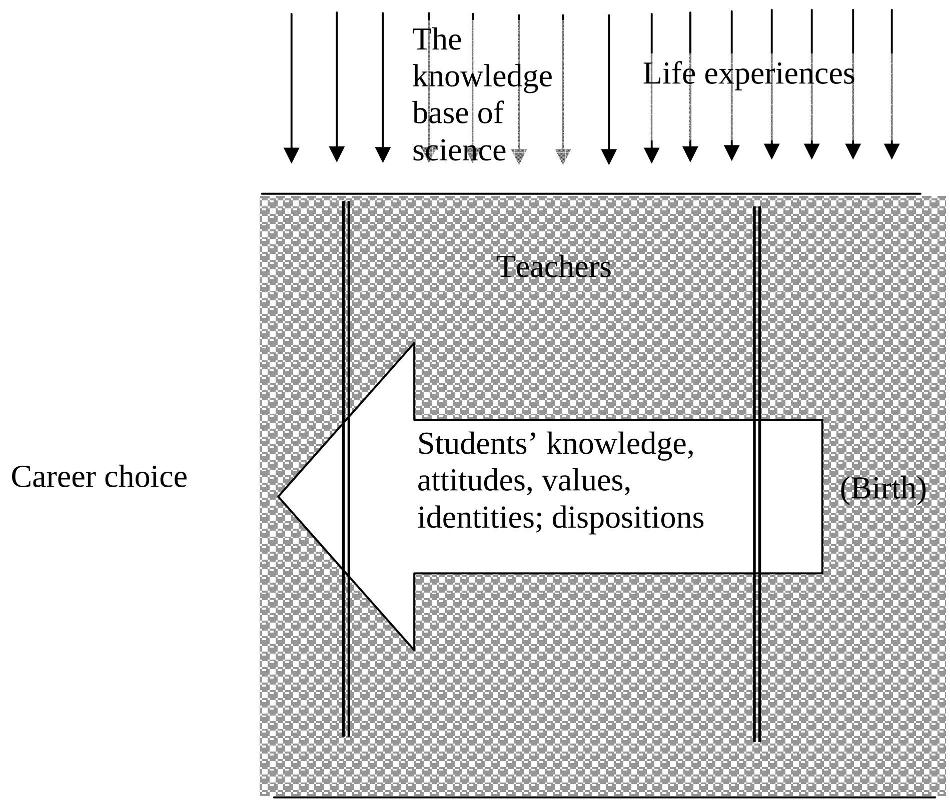


Figure 3.2: Aquifer model of teaching



geology of the formation. For example, acidic water flowing through carbonate minerals tends to slowly dissolve the matrix, increasing the openings in the geologic formation, which then increases the capacity of the geologic formation to conduct or transmit water. In addition, the dissolution of the carbonate minerals from the aquifer makes the water flowing through it more acidic.

Classroom events are analogous to an aquifer (see Figure 2). Like a real life system, there are various sources for meteoric water and groundwater. Some of the meteoric water is analogous to the formal knowledge base accepted by practicing scientists. Other meteoric water is analogous to other sources from which students acquire knowledge such as through personal experiences, reading, and family and community participation. The formal knowledge base is manifested in political documents, such as national, state, and local standards, and is transmitted to the classroom through commercial materials such as textbooks, science kits, and equipment. Teachers are the medium through which this formal knowledge base moves. Groundwater is analogous to the knowledge, attitudes, and dispositions students bring with them to the classroom that have developed over the course of students' lives prior to participation in a particular class. Just as the interactions between the meteoric water, the geologic foundation, and groundwater are complex and variable, so too are the interactions between the formal knowledge base, teachers, and the student knowledge base. For example, teachers may try to remove prior knowledge that they feel is inaccurate. Likewise, teachers make decisions about what material is introduced into the classroom and how that interacts with the prior knowledge of students. Teachers may add to, subtract from, or modify the curriculum depending on their disposition.

This disposition arises from both extrinsic and intrinsic elements. Extrinsic elements comprise experiences teachers have had that may have shaped their ideas with regard to teaching, learning, and schooling. These experiences include experiences with school (as a student), school science, science, teacher certification and teaching, professional development activities, knowledge about their students, and their relationship with the community in which the school is situated. Intrinsic elements are personal characteristics, which may be due to “nature or nurture”, such as beliefs about intelligence being innate or mutable, the strength of these beliefs, and the extent to which these beliefs control behavior. These elements not only influence the selection of content but also the actions teachers take, i.e., teaching strategies, to enact that content in the classroom.

The ground water already in the aquifer is the knowledge, attitudes, values, identities, and dispositions students bring to the classroom. Although some of these come through students’ formal school experiences, school is not the only means through which students acquire them. Families, communities, friends, and life experiences enrich and transform the metaphorical water flowing in the aquifer. Students’ pre-existing knowledge, attitudes, values, identities, and dispositions may affect the teaching that happens in the classroom, just as groundwater may affect the geologic formation of the aquifer. The teaching in the classroom may affect students’ knowledge, attitudes, values, identities, and dispositions just as the aquifer may also affect the water. Regardless of whether or not these teaching events modify students' knowledge, attitudes, values, identities, and dispositions, as water flows out of an aquifer, eventually, students leave the medium of schooling and make decisions about how they will participate in science in the future, such as pursuing careers in science or being scientifically-informed citizens. The funds of knowledge approach developed by Moll et al. (1992) is an example of how "teachers as aquifers" implement the formal content (meteoric water) accounting for the knowledge, attitudes, values, identities, and dispositions (groundwater) students bring to the classroom.

Previous Work

Two earlier studies informed this work. The first one occurred in the summer of 2002, the findings of which were shared at the 2003 annual meeting of the National Association for Research in Science Teaching (NARST) (Austin, Roehrig, & Luft, 2003, March). The second one occurred in the summer of 2003 and these findings were shared at the 2004 annual meeting of the American Educational Researcher Association (AERA) (Austin, Roehrig, & Marshall, 2004, April). A brief description of these studies is given here:

Dialogues with beginning science teachers

During the 2001-2002 school year, I worked as a graduate research assistant in an induction program for a group of beginning science teachers trying to implement inquiry-based teaching in their classrooms. All of the participants had been teaching for less than four years. I observed these teachers on a regular basis and collected several additional pieces of data on them, including a pre- and post-survey of their beliefs about teaching and learning (Luft, Roehrig, Brooks, & Austin, 2003, March) and their views on the nature of science (VNOS-C) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). During the summer, I interviewed six of the teachers, all of whom were working in diverse classrooms. All of the participants had expressed an interest to me, or one of the other researchers, in working with students who were either culturally or economically marginalized from mainstream society. The interviews were semi-structured and were designed to elicit their experiences and beliefs about working in diverse classrooms.

What we found is that even though the teachers were aware of needing to attend to all of their students in designing their curriculum and teaching methodology, they were too overwhelmed with new teacher concerns to design culturally responsive pedagogy. For example, one of the teachers indicated that she felt she was an equitable teacher. However, through our classroom observations, the only practice we characterized as being equitable was her explaining things in Spanish to students who spoke very little English. We saw no evidence of culturally responsive curriculum but instead saw her teaching directly from the district-adopted textbook without any revision.

Development of the VOICE: Views of Inclusion, Culture, and Equity

In preparation for the previous study, I surveyed the literature on equity and multicultural education (e.g., Abdal-Haqq, 1994; Ascher, 1983, 1992; Atwater, 2000;

Banks & Banks, 1995; Banks, 1994; Barnea & Dori, 1999; Beane, 1988; Bianchini, Johnston, Oram, & Cavazos, 2003; Bianchini & Solomon, 2003; Boone, Braile, Krockover, & Rizzo, 1999; Boone & Kahle, 1998; Brown, 2001; Catsambis, 1994; Clark, 1999; Creswell, 1983; Dawe, 1983; DeBacker & Nelson, 2000; Futrell et al., 2003; Jacobs & Reyhner, 2002; Jegede & Aikenhead, 1999; Kahle & Rennie, 1993; Ladson-Billings, 1995, 2002; Ladson-Billings & Tate IV, 1995; Lee, 2003; Lee & Fradd, 1998; Lynch, 2000; Maholmes, 2001; Marinez & Ortiz de Montellano, 1988; Mattern & Schau, 2002; Moll et al., 1992; Oakes & Lipton, 1996; Parsons, 1997; Pena, 1997, April 8; Pomeroy, 1994; Reyes, Scribner, & Scribner, 1999; Rivera & LaCelle-Peterson, 1993; Rodriguez, 1998; Rosebery, Warren, & Conant, 1992; Southerland & Gess-Newsome, 1999; Sutherland & Dennick, 2002; Sutman, 1993; Tan, 2001) and found that there are many points of view about equitable pedagogy. For example, Southerland and Gess-Newsome (1999) and Bianchini et al. (2003) frame their investigations about equitable science teaching practices by looking at the role an understanding of the nature of science plays in teachers' practices. Drawing on the work of Nieto and Ladson-Billings, Atwater (2000) emphasizes the importance of high teacher expectations in assuring equitable treatment in the classroom for African American students. Brown (2001) focuses on making science culturally relevant to under-represented groups, through early exposure to technology and role models/mentors. Moll's (1992) funds of knowledge program helps teachers understand the students' community's knowledge. From these and other readings, I found many overlapping ideas about equitable teaching. I took these overlapping ideas and developed a set of questions for teachers that addressed these ideas. The questions and references that support the inclusion of each question are given in table 1, questions 6-11. Additionally, questions 1-5 were included for reasons cited on the table. Once the questions were established, the survey underwent three changes. In response to the concern of a multicultural researcher, the words "in preparation" were added to the end of the second part of question 6. After giving the survey to group of 15 teachers, the words "as a student" were added to the first part of question 5. After giving the survey to a second group of 12 teachers, the definition and an example of a metaphor were added to question 3. These three changes were made for the purpose of clarification.

Table 3.1: Correlation between theoretical attributes of good teaching and survey questions

1. What does "science for all Americans" mean? How do you enact that in your classroom?	Goal of K-12 science education (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996)
2. What are the four most important things students will take away from your class? 3. What is a metaphor for your teaching? Explain how it characterizes your teaching. 4. How has your life experience affected your learning? 5. How well prepared were you to be successful in school (as a student)? How did you "make up"	Questions 2 and 3 are intended to identify a rationale for teaching. Questions 4 and 5 seek to establish how aware the teacher is of how life experiences affect learning. Seidman (1998) suggests that understanding the background of participants helps situate qualitative data and improves both data collection and analysis.

for any deficiencies?	
6. How well prepared are your students to succeed in your class? What do you do to address any deficiencies in preparation? 7. Describe the life experiences of your students. 8. How does the life experience of your students influence your teaching? How does the life experience of your students affect their ability to be successful in your class?	Awareness and active respect for the backgrounds and life experiences of students is believed to be essential for successful teaching of culturally diverse learners (Banks, 1994; Jegede & Aikenhead, 1999; Ladson-Billings, 1995, 2002; Lee & Fradd, 1998; Pomeroy, 1994)
9. How do you assess student learning?	Assessment should be varied, flexible, and aligned with the values and practices of students' home cultures (Ascher, 1983; Short & Spanos, 1989; Sutman, 1993)
10. What do you envision are some of the most likely career paths of your students? Do you think they will take more science classes?	Students tend to apply themselves more in subjects that they think will be useful in their future (Ascher, 1983; Brown, 2001; Clark, 1999; Eccles & Harold, 1985; Marinez & Ortiz de Montellano, 1988). Consequently, teachers should link the study of science to potential careers
11. How often do you talk to parents? Why? Who initiates the	Parent involvement is cited as an important indicator of student

contact?	performance (Clark, 1999; Scribner, 2001; Sutman, 1993)

Methodology overview

Educational research methods are commonly divided into two categories: quantitative and qualitative (Johnson & Christensen, 2000). Quantitative research involves collection of numerical data that are operated on with statistics in order to test hypotheses (Johnson & Christensen, 2000). The aim of qualitative research is understanding the complexity of human action and interaction and their meanings in a given sociocultural context. It is an inductive method used to generate hypotheses and theory (Johnson & Christensen, 2000). Maxwell (1996) identifies five purposes for doing qualitative research including:

1) Understanding the meaning […] events, situations, and actions [participants] are involved in and the accounts that they give of their experiences
2) Understanding the particular context within which the participants act, and the influence that this context has on their actions
3) Identifying unanticipated phenomena and influences
4) Understanding the process by which events and actions take place
5) Developing causal explanations (Maxwell, 1996, p. 17)

The research questions presented here do not contain a hypothesis nor theory to be tested; rather the purpose of this research is to characterize the ways teachers talk about and enact teaching in classrooms situations in which there is a daily opportunity to successfully negotiate cultural differences in the construction and implementation of educational events. This purpose aligns with Maxwell's (1996) first and second purposes, given above, in requesting participants to give the personal, historical context of their current situation and then subject this history to interpretation. In other words, the object of the research is to elicit those memories, events, and awarenesses that may contribute to the enactment of equitable teaching. Additionally, classroom observations will serve to support interpretation of these data by documenting the current operationalization of memories, past events, and awarenesses. More specifically, answering the research questions entails discerning the extrinsic and intrinsic elements that contribute to equitable behaviors. These elements include experiences with school, school science, science, certification and teaching, professional development activities, knowledge about students, and relationships with the community in which the school is situated. Consequently, qualitative methods are indicated as the method to answer the research questions.

There are many types of qualitative research. Tesch (1990) categorizes 27 types of qualitative research into three broad purposes: determining the characteristics of language, discovering regularities in human experience, and comprehending the meaning of a text or action. This research falls into the last purpose. More specifically, under the purpose of comprehending meaning, she identifies two categories: discerning of themes (commonalities and uniqueness) and interpretation. The goal of this research is to discern common and unique themes in the interview data, using classroom observations as an aid for interpretation. Consequently, in accordance with Tesch's flow chart (Miles & Huberman, 1994, p. 7), phenomenological analysis of data is called for.

The chosen unit of analysis is a case. Case studies "establish the how and why of complex human situation" (Yin, 1994, p. 16). Furthermore, "descriptive case studies provide a detailed description of the phenomenon within its context rather than in terms of existing theoretical formulations. It is hoped the detail provided by the description will generate new insights into, and a better understanding of, the nature of the phenomenon" (Willig, 2001, p. 74). As stated in the theoretical frame, classrooms events are difficult to characterize, i.e., are complex human situations. Since the purpose of this research is to understand one aspect of these situations, namely, teachers' strategies with respect to equity, descriptive case studies are an appropriate method to use to answer the research questions.

One assumption of creating case studies is that it is possible to gain access to thoughts and feelings through participant descriptions and accounts of events (Seidman, 1998; Willig, 2001). "Grounded theory and phenomenology assume there is a relationship between what people say about their experiences and the nature of the experience" (Willig, 2001, p. 83). Additionally, "qualitative researchers […] argue that reality is constructed […] through the operation of language" (Johnson & Christensen, 2000, p. 20). Consequently, interviewing is a method that is consistent with case study research.

The interview methodology used here is guided by the work of Seidman (1998). He maintains that interviewing is the best way to understand the experiences of other people and the meaning they make of that experience (Seidman, 1998, p. 5). He developed a three interview series that he claims is sufficiently long to develop a deep understanding of people's experiences and what these experiences mean to them (Seidman, 1998). The first interview is a life history, focused on the phenomenon under study. The second interview gives the current details of the phenomenon and the third interview requires participants to reflect on the meaning of the phenomenon. The structured, three-interview series advocated by Seidman provided the inspiration for the data collection method of this study. I supplemented his interview design by including questions that arose from my survey of the literature to ensure that participants would discuss issues pertinent to equitable teaching in diverse classrooms. For example, in the first interview, in addition to asking participants focused life history questions, I also asked them about the nature of science, in accordance with Bianchini's et al. (2003) and Southerland's and Gess-Newsome's (1999) focus on the nature of science and equitable teaching in diverse settings. In the second interview, I guided teachers' descriptions of their current experiences (Seidman, 1998) of teaching in diverse classrooms toward specific areas of their practice, such as how knowledge about their students' lives influences their practice (see, e.g. Banks, 1994; Ladson-Billings, 1995, 2002). Similarly, for the third interview, participants' reflections about their current teaching experiences are guided to topics that may be of importance in equitable teaching such as student enjoyment of science lessons (DeBacker & Nelson, 2000; Francis & Greer, 1999).

Data collection introduction

In order to understand how teachers negotiate teaching content, it is necessary to determine what content they are teaching and why, and how they are teaching it and why. Structured and semi-structured interviews give teachers the opportunity to discuss factors that may influence the "whys" such as experiences in school, school science, and certification programs. They also elicit more subtle details such as how teachers developed their lesson or unit plans and their thoughts, responses, and feelings as they enacted these plans. Classroom observations provide the researcher with contextual information necessary for interpreting the words of the participants.

Data collection overview

Data sources

The district in which this research was situated was located in central Texas, a state with high-stakes accountability testing called TAKS (Texas Assessment of Knowledge and Skills). In addition to statewide testing, the district recently enacted instructional planning guides [IPGs] that contain topics to cover, instructional activities, resources, and suggested pacing for topics in all subjects. These planning guides have pop-ups of key knowledge and skills, such as vocabulary words. The district monitors adherence to the IPGs through benchmark tests, which are administered every six weeks.

Schools were chosen based on their demographics, i.e., that the population of Hispanic[1] students was at least 30% but less than 70%. School #1 has approximately 2000 students, 62% of which are minority. The largest group of students is Hispanic (~50%). Whites make up the next largest group (~38%), with African Americans being the third largest group (~9%). There are a handful of Asians, Pacific Islanders and Native Americans enrolled at the school. Science classes average 25 students per class. There are 128 teachers at school #1. 81% of the teachers are white, 17% Hispanic and 2% African American. School #2 has approximately 1900 students, 86% of which are minority. As with school #1, the largest group of students is Hispanic (62%), followed by African American students (20%), and then White (14%). A handful of Asian, Native American, and Pacific Islanders complete the enrollment. Science classes average 29 students per class. There are 104 teachers at school #2: 78% white, 11% Hispanic, 8% African American and 3% Asian. The labels of Hispanic, White, Asian, or African American are not meant to evoke a set of understandings about cultural background. For example, Asian could refer to anyone of a number of very different cultures, such as Japanese, Korean, or Indian. Other facts about the schools include the statistic that 21% of the students at school #1 qualify for free lunch and 46% of the students at school #2 do. 45% of the students at both schools declare they are college bound.

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[1] Hispanic is the term used by the state for demographic classification.

As found in the preliminary study, because of more pressing concerns, most beginning teachers, those in their first three years of teaching, are not able to attend to the concerns of equitable teaching (Austin et al., 2003, March). Based on these findings, teachers who had been teaching for less than four years were excluded from consideration. Eight teachers from these two schools volunteered to participate in the study in response to a solicitation. Their characteristics are given in table 2.1. In addition to these eight teachers, one other teacher at each school agreed to be interviewed once as the "other faculty."

Table 3.2: Characteristics of teacher participants

Teacher	Gender	Ethnicity	Subject	Years teaching
1	M	White	Biology	10
2	M	Asian	Integrated Physics & Chemistry (IPC)	18
3	F	White	Biology	9
4	F	Asian-Mexican[1] American	Biology	4
5	M	Mexican American	Biology	6
6	F	Mexican American	Biology	8
7	F	White	Chemistry	20
8	M	White	Chemistry, IPC	8

[1]The teachers in this study self-identified as Mexican American.

Several sets of data were collected for this study from these two sets of participants:

A. Teachers

1. Focused life history: Semi-structured interview about previous experiences in science and school science and Views on the Nature Of Science (VNOS-C) (Lederman et al., 2002).
2. Details of current experiences (phenomenon): Semi-structured interview about current school placement, current students, and views on equitable teaching (VOICE) (Austin et al., 2004, April).
3. Reflection on the phenomenon: Open-ended interview about their reflections on science lessons taught during the school year.
4. Classroom observations of lesson content, teaching strategy, teacher and student actions, and summaries of discussions.

B. Other faculty

1. Open-ended interview about their views on the environment of the school, including barriers and pathways to enacting equitable teaching. This information aids in understanding contextual factors that may affect teachers' enactment of equitable strategies.

<u>Teacher interviews:</u>

First:

The first interview follows the prescription given by Seidman (1998) in prompting the participant to recount how he or she came to be teaching where and in the manner she was. It aids in identifying the extrinsic elements of teachers' experiences with science, school science, certification, and teaching. It sets the philosophical stage for understanding the current lived experience of the teacher in a culturally diverse classroom. The specific questions covered in this interview are:

Describe your experiences in HS science. What courses did you take? Were the classes interesting? Why or why not?

What was your major in college? What were your college science classes like? What courses did you take?

Have you had any non-school experiences in science (such as summer research, job, etc.)?

How did you get interested in education?

Describe your certification program.

Describe your student teaching experience. What was your cooperating teacher like? (If applicable: What were his or her views on equitable teaching and/or teaching in culturally diverse classrooms?)

Describe any teaching positions you've had, other than this one.

Clarify (or complete) responses from the "Views on the Nature of Science" (Lederman et al., 2002) Questionnaire (see Appendix A).

Second:

Following Seidman's (1998) prescription for the second interview, this interview allows participants to describe their current reality with respect to equitable science teaching. Early in the school year, all the science teachers at these two schools were asked to complete the written form of the VOICE survey. During the second interview, they were given a copy of these responses following which they were given the opportunity to expand or explain their original answers. In addition to the clarifying questions from the VOICE survey, participants were asked to describe the students at their school, their role as a teacher, and barriers and pathways to fulfilling that role.

The purpose of asking these additional questions was to ensure that the participants fully characterized their current experience, in fulfillment of Seidman's (1998) prescription for the second interview. The data collected in this interview are in the form of responses to questions about essential characteristics of equitable teaching as identified by experts. It aids in identifying extrinsic elements: the relationship between the participant and the community in which the school is situated (questions 7, 10, and 11) and experiences with teaching (questions 6, 8, and 9). Questions 4 and 5 triangulate data from interview 1.

Third:

This last interview allows participants to construct personal meanings about their experiences (Seidman, 1998). Rather than allowing the researcher to evaluate *life experiences, it gives teachers an opportunity to review what they've done and evaluate it. Questions covered in this interview include:*

Let's review some of the lessons I've observed (review list of topics).

Discuss the most successful lessons—why were they successful?

Which ones were the most challenging—why were they challenging?

Which ones do you think students learned the most from—why?

Which ones do you think students enjoyed the most—why?

Which ones do you think "reached" the most students?

Which were the most equitable—why?

Which lessons will you change? Why? How will you change them?

In an earlier interview, you thought _________ was a metaphor for your teaching. Do you still feel that way?

Other faculty interview:

In order to more fully understand the lived experience of the participating teachers, additional faculty at each school were interviewed. The purpose of these interviews was to provide additional description about the context in which the participants enact their beliefs. These interviews included the following questions:

Describe the students at your school.

What are some similarities and differences between their life experiences and your life experiences? How prepared are they to be successful in school? In later life?

How do their life experiences influence the school community from an educational standpoint?

What do students at this school do after high school?

What do you see as your role as a teacher at your school? (Or, for administrators: What do you see as your role as an administrator at your school?)

What are barriers or pathways to fulfilling that role?

These questions represent the basic framework for interviewing teachers. Each interview included follow-up questions to participant responses for the purpose of clarifying answers that were unclear, re-directing responses that didn't fully address the question, or extending brief responses.

An example of clarifying answers occurred when interviewing teacher 8. When describing students at his school, one of the adjectives he used was "needy". In a follow-up question, I asked him to clarify what he meant by that term. An example of re-directing responses occurred when interviewing teacher 8 about the nature of science (see Appendix A). I asked him how there could be two different explanations for the extinction of dinosaurs if all groups of scientists have access to the same data. He responded by telling me about a layer of iridium he encountered when working as a geologist for an oil company:

> Well, a lot of people just try to gather the facts that they want to support their hypotheses…part of their research grant, who knows. I think you just have to go back; stand back and look at the evidence and see what all you do have

> and work from there. Like I know back when we were doing it, we did it at XXX, just in our area, because rocks up there [were] exposed. We had a little layer of iridium, right there, exposed, on this nice outcrop. I mean, here it is, you know. And, 65 million years, you might say, where'd the iridium come from? Well, it didn't occur that much in your volcanoes as opposed to meteors…"look there". I mean, most of it, I would say, come out of meteors. If I had a hunch, I would say, yeah, it's meteoric in origin. Because of those types of metals that were dispersed at the time.

I responded by asking him, "In other words, different groups of scientists may reach different conclusions if they don't look at all of the available evidence?" He then started talking about evidence, bias, and conclusions.

An example of extending responses occurred when interviewing teacher 5. I asked, "What were the science classes like [in college]?" He replied, "They were pretty tough but good. They were nice. I learned a lot." I asked him to describe them and got a similarly short response. Consequently, I asked him about specific features, such as whether or not his science classes involved lectures, labs, worksheets, fieldwork, collaborative work, etc.

Data collection specifics

All interviews were recorded on a digital voice recorder and then transferred to a computer. These interviews were transcribed by the researcher and then analyzed using NVivo. Observations were recorded as written field notes and included the lesson content, the pedagogical method used to teach the content, technology that was used, student-student and teacher-student interactions, levels of student engagement, and any other details that seemed salient to characterize the classroom environment. Additionally, materials on the walls and around the classroom, such as previous student work and available equipment were also noted. I then transcribed these handwritten field notes.

Data analysis

Rather than constructing a summary or narrative of the data, I used the raw data as the case. Following Willig's (2001) prescription, this data set included the five features that define a case study. 1) The particularity of an individual case, which can be a situation, an incident, or an experience, arose from the second interview as the participants discuss their beliefs about equitable teaching. 2) Considering the case within its historical context arose from the first interview and the situational context arose from the observations and through interviews with other faculty. 3) Triangulation of analysis was provided for through observations. These classroom observations aided in the interpretation of teachers' interview data by providing an example of operationalization of teachers' words. 4) Studying the case over time happened as the interviews and observations occurred throughout the school year.5) Facilitating theory generation was not specifically addressed since the analysis of this study was phenomenology. However, the cases developed in this research should form a solid foundation for future, purposeful sampling consistent with the beliefs and ideology of grounded theory (Strauss & Corbin, 1990).

Data were analyzed using a phenomenological approach (Moustakas, 1994). The basic methodology included the following steps: 1) A series of annotations including labels, issues, associations, questions, and summaries were generated while reading through the data. Consistent with the principles of naturalistic inquiry, this process was iterated until no new annotations were made. 2) These annotations were grouped into themes based on similarity of underlying concepts. 3) Clusters were generated from the themes based on shared meanings.

Validity and reliability

Validity refers to the appropriateness of inferences based on data (Johnson & Christensen, 2000), in other words, whether or not the measurement instrument really measures what it purports to. Lincoln and Guba (1985) contrast the quantitative research criteria of “internal validity” with the naturalistic criteria of “credibility” and “external validity” with “transferability.” For them, credibility lies in the richness of information obtained, thorough analysis, and triangulation of findings. Transferability is a function of the similarity between the research situation and a different one. As with credibility, transferability is enhanced by obtaining and reporting thick descriptions of the context and phenomenon. Reliability refers to the consistency of measurement or the stability of the measured variable (Johnson & Christensen, 2000). In general, “qualitative researchers are less concerned with reliability" (Willig, 2001, p. 17), however, Willig allows that the same data analyzed by different researchers should yield similar findings. "Reliability can be demonstrated by using triangulation (of researchers and/or of methods) to show how different perspectives converge and thus confirm one another's observations and interpretations" (Willig, 2001, p. 146).

Credibility and transferability are addressed in the type, quality, and amount of data collected, the analysis and triangulation, and the reporting of data. These issues have been addressed throughout this chapter. Some of the data were purely factual in nature, such as the science classes teachers had taken in high school or the nature of their teacher certification program. These data were collected, organized, and reported in tables, where appropriate.

Other data, although qualitative, had a clearly delineated beginning and end. These data were analyzed and reported as a single set in the manner described in the previous section. For example, on the VOICE, teachers were asked what four things they wanted students to walk away with. Responses were coded into four categories (see Appendix B for an example of this type of analysis). Reliability was checked as follows: All of the statements teachers made to this question were given to outside researcher A. The researcher was shown the initial coding scheme but did not study it. Researcher A identified five conceptual categories for the 32 responses, labeling each response. Although the labels themselves were different, the researchers agreed on the categorization of 28 of the 32 responses, 87.5% agreement. The five discrepancies were discussed and resolved as follows. One of the responses was in a category not identified in the initial coding scheme, “encouragement.” The conceptualization of one of the categories, “personal attributes” was modified and that response as well as another one was placed into that category. Two responses were moved into different categories, based on researcher A’s coding scheme. The remaining response remained where it was, based on other statements made by the participant.

In addition to analysis of subsections, each interview was also analyzed holistically in the manner described in the previous section, looking for themes relevant to issues of equity. Reliability of this coding was checked in the follwing way: I wanted to insure that I wasn’t missing important statements or including unimportant ones when I was making annotations for identifying statements of interest. I gave 15 pages of transcript comprising responses from three different teachers to outside researcher B. Researcher B, who is familiar with NVivo, free-coded the transcript, identifying statements of possible interest. NVivo is a flexible program that allows for multiple and overlapping coding of statements. This coding was compared to my initial free coding. Researcher B identified 93 statements compared to 126 I identified. The differences were discussed by doing a statement-by-statement analysis. Seven of the statements identified by researcher B were not identified in the original analysis. However, none of these statements contained new concepts not represented in at least one of the original 126. One of the major points of discussion was starting and stopping points for a “statement”. For example, given in the following dialogue between the teacher, “R,” and the interviewer, “B”:

R: And I use all these theories…and it get results. The problem is when it gets results, people not recognize it. It's not only not recognized but it's being blamed.

B: It's not valued.

R: It's not valued. I show them the results. You can see what I got. You can see the top 5 in this class. But they do not recognize this. They just do their job. And that is the problem.

I coded R's responses as two separate statements of interest whereas researcher B coded it as one. After discussion, we decided that in principle, we had identified similar statements of interest although the actual portions of the transcript coded were not identical.

Limitations

The target setting of this study was culturally diverse schools. As noted previously, ethnicity is not an indicator of culture. However, institutional demographers, such as those who characterize school populations, do not track students' cultures, only their ethnicity. It was beyond the scope of this work to conduct an ethnographic study of the school setting so the limited demographic data were used. Descriptions of the student body from the "others" involved with the school supplemented the limited demographic data. Thus, since the cultures of the students of the teachers in this study were not identified, the exact extent or even existence of culture diversity present in teachers' classrooms is undetermined.

Two issues limit the generalizability of this study. First, the teachers volunteered to participate and were therefore did not comprise a random sample. Since they were not reimbursed for study participation, their volunteering for a study concerning equity implies a predisposition to be concerned with this issue. Consequently, their views and practices may be more equitable than the average science teacher. Second, the small number of subjects from a single school district that tries to make teaching throughout the district uniform, also limits the generalizability of the data.

Several recent studies have noted that teachers' description of their practices do not always match what they do in the classroom (e.g., Simmons et al., 1999). Originally, classroom observations were supposed to be used solely for the purpose of verifying interpretation of interview data. However, as I analyzed the interview data, I realized there were frequently large variations between how teachers characterized their practice and how I characterized it. Unfortunately, this realization did not occur until the majority of observations were completed. Because of the original intention of the observations, these data were not detailed enough to support the gap between rhetoric and practice.

Another limitation concerns interviewing as a method of data collection: equity is a politically charged issue. Participants may have felt uncomfortable being completely open and honest about their practices and feelings about students. As the findings will show, there were discrepancies between how teachers characterized their practice and their observed practice. This discrepancy may have been an artifact of the interviewing process or the result of inaccurate self-assessment.

CHAPTER FOUR

FINDINGS

This chapter is arranged in two parts. In the first part, I introduce the teachers who took part in this study. In the second part, I introduce themes that emerged from the data.

Part 1: The teachers

Teacher 1

Teacher 1 is a White male who teaches biology. His high school science experiences were very limited. His college science experiences were completely different. He describes his major department as one of the premier departments in the field at that time that was dedicated to the development of their students. He recalls,

> We had one of the first electron microscopes that was available, for example. And, many of us were trained in the techniques for the use of that, in the preparation of materials for that, not because it was course work or actual research, simply because our faculty felt that it was important that we be exposed to that.

He says his schooling emphasized, “hands-on things, experimentation, asking questions,” with a focus on not only,

> […] the technical education, but how did the technical information that you’re acquiring get used. How did you use it? What kinds of things can we extrapolate? What kinds of things can we make a leap with and see what’s happening? What kinds of questions can we come up with and find answers to using some of these techniques and some of the equipment we’ve got?

He almost completed a doctorate in botany, specializing in plant pathology but quit during the last year of his degree because of family circumstances. After a tour of duty in the military, he worked for the state and then as a private consultant in the area of rehabilitation claims. He worked as a long-term substitute for several years before getting a teaching certificate through an alternative program.

Teacher 1’s love for science is revealed in the enthusiasm of his manner. Although his teaching dialogue is sprinkled with statements that connect what he teaches with the activities of practicing biologists, he believes the primary goal of science teaching is to produce scientifically literate citizens. For him, the essential part of scientific literacy is being able to obtain information and then analyze it to make a logical, evidence-based decision. For example, he says:

> I’m not trying to turn out biologists, or chemists, or astronomers or anatomists or whatever. What I’m trying to do, and what me and my group are trying to do is turn out scientifically literate citizens. Scientifically literate. Know how to look at information they’re given and say, “hey, I can

> accept that," or, "that's bull"; to know how to ask questions and how to look for information. To know how to ask those questions and assess the information they get and come to conclusions. We're dealing with the scientific method, you know, that's what it's about.

He goes on:

> I try to teach them and show them and get them to come to understand on their own terms without an old fart telling them what's going on that, hey, they're doing science all the time. They're asking questions. Maybe it's not about biology but they're asking questions, they're gathering data, they're evaluating the data they gather. They're making decisions based upon the data. What is that if it's not science?

In subtle contrast to this emphasis on critical thinking, teacher 1 controls the thinking that occurs in his classroom. He says, "I pose questions that they've got to answer, and provide them with the resources. It may be resources from my lectures, from the laboratory, from references I provide them with." As implied in this statement, there is a lot of dialogue in the classroom, but teacher 1 controls the dialogue. He goes on, "I provide things for them to look at and ask questions about. I provide them with techniques. I provide them with answers, and guidance." In another instance he says, "One of the things I sometimes do is give them an assignment for them to go dig out information." Another contrast to the rhetoric is the type and nature of the assessments that count towards grades: quizzes, written work, and tests covering content knowledge.

He has had experiences in informal education where students' motivation and skill acquisition was greatly enhanced through working on projects. For example, he tells his current students about how working on housing construction projects helped "at-risk" students understand the relevance of geometry and algebra, aiding their understanding of math concepts in these disciplines. In light of this experience, it is ironic to see a fair amount of content is delivered through lecturing in his classroom. He explains,

> Sometimes what I provide for them is straight-out information. I'm a biological scientist. I have a heck of a lot of information stored in this brain; I've been working in this field for 40 years.

Teacher 1 actively disagrees with his perception of the district's philosophy of preparing all children for college. He says,

> For many of our cherubs, we're offering them the last science courses they're ever going to have in their life. Many of them are not going on to college. And that isn't a popular position or a popular position to take but the fact is, number one, not all of the students that exist in high school are college level material.

In another interview he stated,

> Not all of the students are college level material, could not make it on their own in the college environment. And not all of them have a life focus that requires that. They don't want to go on. They have no reason to go on.

Science as critical thinking is consistent with his college science training. His manner of speaking about his students could be considered patronizing by some. For example, he typically refers to his students as “cherubs”, as in an above quote. When discussing his beginning of the year routine to teach students about the nature of science, he states, “We learn how to formalize it and then we get into the meat of the curriculum, but, with as little trauma to their delicate psyches as I can manage.”

Teacher 2

Teacher 2 is an Asian male who teaches Integrated Physics and Chemistry (IPC). He was born and spent most of his life in Hong Kong, teaching science at the secondary and college level. After these experiences he worked as a teacher educator and then as a principal before retiring. After moving to the United States (US), he decided he needed to do more to “give back” to society. He returned to school to get certified; this is his second year teaching in the US.

Through his experiences in Hong Kong, he became a strong believer in the transformative power of education. While working as a principal at a school with low-performing children, he started implementing practices he read about in education journals that were based on research conducted by teacher educators at US universities. He explains:

> It is a real luxury for me to see education in action. I can really see that education can really help transform a person’s life. And that is not just lip service—even those in the field of education do not believe it. At first I do

> not believe it either. How could a process change the person that much? But it really did—especially when I was the principal. The first year, I taught the top students. The second year, I become the principal of the bottom students so I got to see both. I can say, really, the education process, if it is implemented correctly, can really change a person's life. Therefore, I had the luxury of seeing that.

He continues by talking about how the students at this school had a reputation for destroying school property. However, after teacher 2 implemented reforms, students not only stopped destroying property but started achieving high scores on national exams.

He has tried to mirror his success with students in Hong Kong at his current placement but has been frustrated by institutional apathy. He feels his efforts are unrecognized and dismissed by administrators and other teachers. He expresses concern about this situation because of the negative effect on children. He observes that the best and brightest students will learn regardless of the teacher and the teaching methodology. His interest lies in teaching those students for whom learning is challenging but also critical for future happiness.

Teacher 2 makes several criticisms about teaching methods at his school. First, he believes that students are over-controlled by school rules and authorities. In contrast, he believes placing students in leadership positions contributed to his success with students in Hong Kong. Second, he believes students are under-challenged by school. He asserts that if lessons were more demanding and informative, students would be more interested in learning. Finally, he disagrees with the instructional goal of engaging students, which is prevalent at his school. He explains,

> To me seems, what is now “engage” is how to manipulate students so they can be occupied so they do not give problem to the teacher and then you go through the whole period safely, peacefully, but I’m wondering, because I’m teaching the students and learn how they are taught in the past and how their foundation is. It seems to me they do not learn that much, really. And you can just pass them through a period and engage them in group activities. That is fine but I’m wondering how much they can learn.

Later in the discussion I asked him a clarifying question, “In other words, they must have some content before they can operate on it?” He explained,

> Before they can contribute. But they don’t seem to. Because they cannot even discern which one is more important, which one is more basic, which one is more the root problem to the whole topic. They cannot discern that, they can just get some information from the book. Therefore, usually they cannot grasp the basic skill in math and science. They may have some knowledge that they got in their past. I think this type of engaging is not very functional. It may benefit those bright students who can read the book and get something out of it but not for my students.

In spite of his low assessment of his students’ abilities, teacher 2 challenges his students. He is very skillful at asking provocative questions that elicit conceptual responses from students, rather than simplistic regurgitation of factual information. He continually asks his students to justify or explain their responses. The most interesting thing about his teaching method is his ability to validate students' answers regardless of whether they are right or wrong: he recognizes and values responses that show critical thinking and use of evidence to draw conclusions independent of the rightness or wrongness of the answer.

Teacher 3

Teacher 3 is a White female who teaches biology. When she was very young, she got interested in science after playing with her brother's chemistry set. Ironically, in high school, she found chemistry very boring. She explains, "The chemistry teacher gave the same lectures every year. You could tell from the chalk dust on the pages. When you went into his office, he had all his notebooks for each unit on the shelves." Her freshman biology teacher offered her a summer research internship working at a marine institute. She recalls,

> That summer was really good. Before that, I didn't know what I wanted to do. I didn't know any scientists, you know, all I had in my head was the scientist in a white lab coat at a workbench [laughs]. And suddenly, I catch myself and, whoa, I'm feeling like Jacques Cousteau. It was fun.

She says her summer internships gave her the perspective to make it through her science courses during the school year. She explains, "I would do so much during the summer—you know really be involved. But then, two weeks after the semester started, I'd be looking around [her science class] and going, 'what am I doing here?'[laughs]" She finished her degree and got a job in an animal research facility. However, she found the job unsatisfactory due to the nature of the work and never feeling part of the group of scientists. She recalled that it wasn't "the right place for me."

Teacher 3 is a teacher that students talk to. Students coming in to see her about various class and extracurricular issues interrupted every interview we had. Surprisingly, teacher 3 is very straightforward when she talks to them. For example, she shared the following experience:

> I despair over the girls that come to me [who are pregnant]. A few weeks ago, one of my best students missed a couple of days of class. She came to my room after school and told me she was pregnant. […] So, we sat down and started discussing options. I think she understood why staying in school was important…you know, that she needed to finish her education and not just quit and be on welfare. But it's hard to make them understand that not finishing school has negative consequences.

In commenting about her students' life experiences, she talks about "families that are struggling to survive and don't much care about education --they'd rather send the kids out to work." Teacher 3 says she talks to them a lot about why education is important and that she is there to help students who want to succeed. About her classroom policies, she says,

> Of course I let students make up missed work, I mean, I have to, but they have to produce something to show me why they didn't do the work […] like a note from their parent or a note to me, you know, from them. And, they have to tell me what they are going to do to avoid missing work in the future [laughs]. I don't know, maybe I've been teaching for too long but I'm not willing to allow the kids to do, you know, anything.

When asked how students respond to this treatment she acknowledges that some of them respond more positively than others but thinks that overall, most of them accept the policy.

Another quality about teacher 3 is the effort she puts into encouraging students to engage in her classroom by recognizing student efforts. Every time I visited, she had different student work on display. In my prior experiences in observing classrooms, teachers usually leave the same student work up, changing it only once or twice a semester. On one of her boards, she had a "work of the week", an outstanding student paper, posted. She explains, "This environment isn't very encouraging. Doing well in school is not cool. I try to make it cool in my classroom." In another interview she talks about how there is a visible group of kids within the student body whose comments and general demeanor discourage students who might otherwise apply themselves. She says, "Carrying books or notebooks is the antithesis of cool." In response to what she does to change students' attitudes, she says,

> It's really hard when I have a couple of students who just sit in the back, you know, you can just tell by the way they're sitting [makes gesture]. I squelch

> that attitude early in the year and make it very clear that's not acceptable in my class. […] I move them to the front and have them do things, you know, like turn out the lights, or pass stuff out and after a while, that sometimes takes care of it, you know, make a big deal of thanking them in front of the class, and…

Teacher 3 is discouraged by her perceived lack of success as a teacher. She says, "I believe in creatively teaching but I also believe the students are responsible for their own learning and my frustration comes from their refusal to take responsibility." In response to how her teaching is affected, she explains, "I've had to rein in on my normal vocabulary, reduce material to lower levels (simplify), and give tests with few higher level questions." She expresses dissatisfaction in not knowing how to elicit better work from her students—she realizes that what she is doing is not working that well but doesn't know what else to do.

Teacher 4

Teacher 4 is Mexican-Asian American female. Her high school science classes involved traditional lectures, laboratories, and library research-based projects. Like teacher 5, she was able to go to college because of an athletic scholarship. Her lack of confidence in her academic ability almost prevented her from going to college. She explains, "I just felt, really, low, when I went to college. I didn't feel very confident in my abilities…I can't read, I can't write, I'm horrible at calculus, I can't do anything right." One of the teachers she had in her first year changed those feelings by pointing out positive aspects in her assignments and encouraging her. Teacher 4 explains, “She really made me feel like I could do it. She believed in me and I believed it.” Teacher 4 got interested in science when taking anatomy, which led her to want to become a physician’s assistant. Life circumstances led her to teaching. She sees herself as a role model for her students, not because of her ethnicity but because of her life experiences, which are similar to those of her students.

Teacher 4 seems to want to fulfill the same role in the lives of her students as the professor she had in her first year of college: believing in her students’ academic abilities. When asked about the quality of her students preparation, rather than saying “good”, or “poor”, she responds,

> I think it has a lot to do with their home life and their prior experiences at school. Like I’ve said before, I can usually tell which schools students went to and the ones who have really been encouraged and the ones who really want to learn and the ones who haven’t or who have no expectations and are kind of just, like, “Why am I here?”

She continues, “I think, still, regardless every student still needs to learn how to learn.” She contrasts this point of view with other teachers at her school:

> [They say] “I’m going to be these children’s savior,” or, “I’m going to be this martyr and sacrifice my life for them.” You know, it just kind of has this common thread, and I just don’t see it that way. I see it more of like, no, I’m going to facilitate. I feel like I’m a facilitator. I will, you know, I want to help

> them learn. I'm not there to just teach them, I'm there to teach them how to learn.

She feels some teachers at the school have a negative attitude about the students. She explains, "A lot of them have been teaching for so long that their demeanor is just kind of, they just have this gray cloud around them, and if they're coming my way, I try to run into my classroom." She recalls:

> I remember one teacher who came in for one of our big presentation days and the teacher was so surprised, saying "I had no idea our students could do that." And I just looked at her, and thought, "Did she just say that? No wonder, you know, if you don't expect things out of them." But she has been teaching forever and I think she's just…

Teacher 4 sees a clear connection between her teaching and life outcomes for her students:

> And I'm there to teach them how to become critical thinkers, or at least discover opportunities so that they can choose. And if they choose, then they can learn from their choices and then they'll carry that skill, not just, they won't leave that at school. They'll take it home. And if their family values are different than their own beliefs, then this child starts espousing his own beliefs, then he'll do something with that. I mean hopefully for positive gain [laughs]. I'm there to help them to discover that they have opportunities, so they have choice.

Although she has aspirations for her students to succeed in life, Teacher 4 acknowledges the need to be sensitive to their current situation. She explains:

> There are certain values and standards that I uphold in the classroom that are different from the values and standards they have at home. […] It's not so much, I'm not trying to tell these kids their values are wrong, I'm just saying, […] when you are in this classroom, you will abide by the standards that I put forth. At school, they can't hit other students. […] But at home, they're taught if someone hits you, you hit them back. So I can't tell this kid, it's wrong to hit. Maybe in their lives, they will have to hit somebody, you know, if they have to defend, I don't know, for whatever reason. So as long as you're with me, you're not going to hit.

Teacher 5

Teacher 5 is a Mexican American male who teaches regular biology. He was the only teacher who regularly participated in hands-on science activities in high school. However, past high school, his science education became very traditional. His main interest in science stems from a desire to want to know how things work. His goals as a teacher are affected by a life-changing experience he had in a course that he took as part of his Master's program about managing diversity. He realized that up to that point in life, because of the way he was raised, he had always tried to overcome being of Mexican descent. He recalls an incident that occurred when he first moved away from home: "I didn't want to be associated with that either [being

Mexican] and I sort of pushed back…like, I came [here] and people would say, 'you know you don't talk like a Mexican', and that was actually a compliment to me." Since taking this course, his idea of his role as a teacher has changed. He says, "I just hope I'm strong enough […] to be able to model to […] these kids…you know I tell them…be who you are, and understand that and work from there."

Teacher 5 is conscious of his position as a Hispanic teacher of Hispanic students. Although not explicitly calling himself a role model, he is conscious that he can speak to their condition in life. He says,

> You know I'm like a lot of these kids in here, economically speaking, their parents are lower middle class, middle class at best. So, it took me time to understand that there are a lot of similarities to my kids [students] when I have to take a step back and say to them, 'I made poor choices, you're going to make poor choices but just go on, be strong, and do what you can.'

When asked about his role he says,

> I think maybe more as a mentor, really, I think that would be…they're just kids, I think that would be my defining role, more of a mentor, someone who is a…role model. We have a lot of Hispanic males and females. Being Hispanic, I think that's probably the biggest role I could play with these guys.

Much of his classroom behavior is based displaying positive personal attributes. For example, he says, "I guess I just try to be consistent. Let them know that they can succeed." He shares his life experiences with his students, "I try to talk a lot about that they can do it, it's a golden opportunity. I tell them that I was a poor student when I was in high school and it can be done and it's important." When assuring his students that school is important, he says, "You know I try to be as genuine as…and I am genuine when I say that but, some of them get lost. And I think there are those that understand, and maybe in this age group it's difficult for them to really associate themselves with that type of success, especially since it's never been modeled for them." He continues, "I try to validate them, and try to respect them. I tell them, that's my biggest rule, there is a rule here, is to demand respect."

<u>Teacher 6</u>

Teacher 6 is a Mexican American female who teaches regular and honors biology. Unlike teacher 5, she never talks about herself as a role model for her students due to her ethnicity. When growing up, she took pride in being a woman in science,

> I think part of it also, was being female, I wanted to be in good in math and science. I felt that was a challenge for me. You know, when you're smart and female, people always expect you to say, "Oh, I'm an English teacher. I'm a, you know, social studies teacher." They always expect you to be into poetry or art, or something like that. And I was no, I'm going to do, I wanted to be, like, chemistry or, something that people would be like, "Whoa. Really?"

Both during and after college she did scientific research for employment. She found her college science classes boring and tedious and almost changed to a non-science major. However, her college job gave her authentic experiences that rekindled her interest in science. She explains,

> Then I started getting hooked up with people who were in zoology…people who majored in zoology were working [there] also. And then I started to realize, oh, I am supposed to be in natural sciences. And that was when I realized that zoology was what I really wanted to work in.

After graduating from college, she completed an internship with the Smithsonian Institute that left her ambivalent about pursuing a science-based career. She explains,

> I just did some goal-setting stuff and I realized I just really like science, and community service and all that stuff and it all kind of dawned on me that I should try teaching. So, I tried it and luckily for me it's worked out really well.

Teacher 6 makes a lot of reflective comments about the students at her high school. In discussing students at her school, she notices,

> I really believe, like in our high schools right now, a real problem that we're having is this dichotomy between the regular education courses and the honors courses. Because there is this in-between…in the regular courses you end up with this element that just don't care and they end up dragging the whole class down. And you end up with these students in the regular courses who are too smart to be in there but they aren't really ready for the honors classes…the level of work, is not really there. So, it's unfortunate that they

> get stuck with these…dumbos. Oh, I shouldn't say that, but, with students who aren't motivated, who aren't willing to put forth any effort.

She observes both positive and negative things about them. For example, she says,

> The students are, I would say the majority of students are interested in learning and are really good students and really interested in doing the right thing. Unfortunately, there's a minority, a powerful minority of students at that school that kind of steer many of the kids the wrong way.

Although all of the teachers interviewed talk about students as groups of high or low achievers, teacher 6 discusses at length factors that may have contributed to their placement in each group. She believes that family organization and previous school experiences influence the motivation and therefore performance level of her students. For example, to the comment above, she adds, "I think that there are some social pressures there that make it difficult to make it be successful unless you have a strong family unit and someone who's, you know, really kind of checking in on you."

Given the strong effect of family experiences on students' behavior, she feels her ability to enact effective teaching is limited. Additionally, the large numbers of students and limited time spent in class also affect her ideas about effects of teaching. When asked about her role as a teacher she says, "Well, with a 150 kids, it's hard to really do more, much more than just, you know…I sit there, I work with them in class, I try to, as I said I work [with them], especially with the regular students.” She goes on, “I don’t really know how to get that behavior to change in one class of one year, you know?” She also observes,

> I think a lot of what…I think a lot of the problems with our schools…I mean we’ve done everything. How many reforms have there been? How many different ways of teaching? And this and that and the other, and I do believe that that’s valuable but at the same time, I believe the problems our kids are having are really outside of the classroom and that for our schools to be successful, that’s where our money and support needs to be.

Teacher 6’s response to meet the needs of her students is to be extremely organized. In talking about management of regular classes, she explains, “I try to, well with all of my classes, keep it very organized so they always know what to expect. I try to help them with, like organization and management skills.” Another approach is to try to make the class enjoyable. She says, “Even if you aren’t interested in science, you might be motivated to do well in the course if there’s humor, if you enjoy the class, if you have a positive feeling about it.”

Teacher 7

Teacher 7 is a White female who teaches chemistry. Her interest in science began in late elementary school when she started working on science projects for yearly science fair competitions. Her father was a university-based scientist who helped her decide on a topic to present each year and provided guidance for completing projects. Although she was a good student in high school, college was challenging because of perceived gender barriers. She explains,

> I was given a full scholarship in chemistry at an institution that had just gone co-ed and had to permit women into the Sciences, so I had to out-chemist the boys—who were really nice to me—in order to convince the professors I was in fact educable.

Although she majored in science, she entered college with the intention of becoming a science teacher. She says,

> I never considered anything else. You know in my day, women only did certain things. Although I had enough nerve to go into science once it was open, I was still operating with, you know, the same ideas I had about what I could do, that I grew up with.

Both her high school and college science classes were very traditional; hands-on work consisted mainly of verification labs. Her cooperating teacher had his students do a lot of labs but these were very scripted. However, she observed the students learned a lot from them. She recalls:

> Everything was very organized so students could use the time for really thinking about the procedures they were doing. I've always done that […] so my students can relate the principles I teach them with what they are doing, instead of struggling to try to figure out how to do it. […] I always have stations set up for them so they can come in and start right in.

Her positivistic views of the nature of science leads to a focus on teaching "the fundamentals of chemistry", meaning, the facts and concepts typically found in textbooks. She identifies her role as transmitting the knowledge base of the mainstream culture.

Although she has specific themes that she tries to reinforce throughout the year, these aren't overarching theories. For example, in justifying why she teaches density early in the school year she says,

> Students have to really understand the concept of distance between atoms. I just think they understand everything better if they understand that atoms are far apart from each other and how far apart they are depends on their state. So I do a lot of activities getting that idea across

Throughout the interviews, teacher 7 repeatedly discusses the importance of doing hands-on activities to promote learning in her classroom. She takes pride in saying that she was doing them long before the district started advocating them. I observed her students doing lab work every time I observed. However, these were invariably verification labs in which she demonstrated the entire procedure prior to students conducting the experiments. Additionally, she told them exactly what they would observe. For example, in one lab on identifying elemental ions, she pointed out that if they didn't observe a particular color of precipitate after one step, it meant they had done the procedure incorrectly and needed to start over.

Of all the teachers, teacher 7 seems most disconnected from her students. When talking about the preparation level of her students she says, "That depends on the student; some are better prepared than others. I teach to the middle and get them to help each other.” She is the only one who didn’t relate a single anecdote about her students. When asked about their life experiences, she responds, “I only know them from being in the classroom and extra curricular events—I don’t know any of my students personally or well enough to discover their life experiences.” When asked about how their life experiences influence their ability to be successful in her class, she says, “There are always outside influences that enhance or detract from my students’ ability to learn. Some kids live horror stories outside the classroom and still succeed. Some have every advantage and mange to fail…isn’t life grand?”

Teacher 8

Teacher 8 is a White male who teaches chemistry and IPC. Since he lived in a small rural town, like teacher 1, his high school science classes were limited in number and traditional in nature. Most of what he knows, he attributes to self-study, “Got most of my education outside of school by reading [the] encyclopedia and other books.” He pursued a Geology degree in college due to a boyhood interest in rocks. His college science classes involved hands-on assignments that were prescriptive in nature. He recalls,

> I guess the biggest thing that I’ve done, was the summer field trip where we went out and not only had to do the contours but we had to do the bedding planes, and rock types, and just do a whole geological makeup map of the whole area. That took all summer.

A downturn in the economy led him to teaching. After a few years he left the classroom to work as a corporate scientist but then returned to teaching after another downturn in the economy.

His positivistic view of the nature of science infuses his science teaching. In explaining his definition of science as factually oriented, he says,

> Anything that you can see, or put your hands on, or try to quantify in some form, as opposed to, you know, philosophy or religion or something along those lines, which is all basically theories. Now in science, we have theories too, but I would say it's more applied, as opposed to just theoretical.

In explaining whether or not science is socially situated, he says,

> I believe it [science] should be strictly based on fact, not fiction. […] But I do know that science is affected by religion and politics, quite often, you know, like in the choosing of textbooks, and things like that. I think it should just be based in fact, strictly based in fact. Now you can get off on your theories and things but make sure that you focus and let the students, and future learners, know that you need to look strictly at facts, nothing else. It's not fiction you're teaching here. And if anybody wants to bring up that kind of stuff, fine and dandy, I guess, but I do think it needs to be universal, around the globe.

When asked if facts are indisputable, he says,

> Sure, they're indisputable, I think. 2 plus 2 is 4. Are you going to try to tell me it's 5? See what I'm saying? Once you see something and you know for a

> fact that it's occurred, you know, I don't see how anyone can tell you otherwise, based on some kind of theory or belief that they're wrong. I truly believe that people need to base their opinions strictly on fact and I've probably put that word fact in there a dozen times but that's what we seek.

Throughout his interviews, he repeatedly discusses the need to teach so that his students will master the material necessary to do well on the TAKS [Texas Assessment of Knowledge and Skills] test. For example, when explaining why he lets students redo or make up assignments, he says, "That's what we're here for, to make sure they've mastered the material." When talking about how much time he spends on lectures versus labs, he says,

> But, there's so much to cover as what is said in the IPG [instructional planning guide], or that has to be covered according to the state. And to try to get the kids to master the subject, 'cause otherwise you're gonna find that you're not going to cover the material if you do too much lab because these kids, like I said, are so needy, you got to constantly reinforce those concepts.

Prescriptive content is an important thing for teacher 8. In discussing the IPGs, he says,

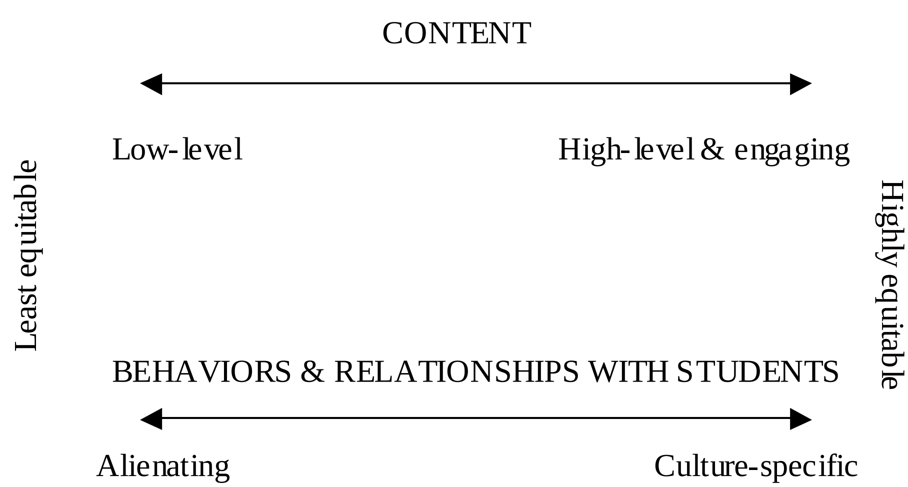
> I love 'em, actually. I think they're excellent. I've been hollering for 'em for ages, ever since I was teaching, at the other campus. And, uh, well, they really didn't start them until recently, but we had something similar, along those lines, when I was teaching math. We had some guidelines to follow that we were supposed to be on within a day or two. That way when kids, there's

a lot of mobility in our schools. So, if kids go to one, they can pretty much just pick up where they left off. And I always called for that in every course in every grade level, vertical, as well as horizontal alignment.

Part 2: Content and method

Ideally, teachers would characterize their practice by describing the strategies identified in chapter 2, which did not happen. What emerged from the data was that teachers' operational values about teaching content and the behaviors they enact can be categorized along two dimensions: content and behaviors and relationships with students as shown in figure 4.1.

Figure 4.1: Continuum of teacher beliefs



Teachers who enact strategies that are highly equitable with respect to content teach the subject matter in ways that engage students in learning what they will need to know in order to be successful in future science courses that lead to a career in science. Teachers who enact strategies that are highly equitable with respect to behaviors and relationships to students have deep knowledge about students' lives and behave in ways that encourage students to self-actualize. The central finding of this research is that teachers enacted many of the strategies articulated in chapter 2. Many of their operational values placed them on the equitable end of both the content and pedagogy spectrum. However, their efforts to teach the content they felt was important for students to know were not informed by the relationships they formed with students. This section details teachers' characterizations of their practices and reveals this disconnection between these two aspects of equitable teaching. First, I identify and discuss teachers' responses that concern content-oriented characterizations and beliefs. Second, I present behaviors and relationships-oriented issues. In the third part, I discuss where each of the teachers falls on this diagram.

Content-oriented strategies

In this part I present themes that inform my interpretation of teachers' ideas about content. Generally, teachers have a one-dimensional view about content which is that science is inextricably situated in the culture of the mainstream. These views appear to stem from their prior experiences with science and beliefs about what students need to know and be able to do in order to be prepared for local and state science exams and success in future classes.

Prior experiences in science

None of the participants remember very much about their high school science classes. Their responses consisted of overall impressions, rather than of specific events. Teacher 2 related that there were no labs and the teachers changed 3 or 4 times a year. Teacher 6 said, “I don’t remember too much about my high school science classes…in biology I only remember the dissection but I’m sure my biology teachers would probably cringe at that. I’m sure we did a lot more than that.” Similarly, when asked whether his high school chemistry class included experiments, teacher 8 said, “A few, a few, not too many. They were more book-oriented, unlike today,” without elaborating.

Teachers generally took the usual high school classes of biology, chemistry, or physics. Participants remember the method of instruction was fairly traditional, in that the teacher controlled the course content rather than constructing curriculum that was responsive to the interests and culture of the students. Most of the teachers reported that their teachers used a textbook as the basis for instruction and the origin of practice problems. Teacher 1 observed:

> The science teacher was more valued for his basketball coaching skills than for his scientific knowledge, and that’s just the way it was. So, my high school science was very basic. My high school science did not require me to stretch my brain and thought processes because, basically, that wasn’t what the science teacher was about (teacher 1).

Teacher 3 remembered her science teachers "just basically repeated what was in the textbook." "We never did anything cool, like go to Sea World or anything…A lot of library research. That's all we pretty much did and then we had, like two projects for the semester" (teacher 4). Another recalled, "I don't really remember doing any projects or anything. I think it was mostly just like [book] work…I don't even remember doing any labs in chemistry. I remember doing a lot of labs in physics" (teacher 6). Teacher 7 recalled doing a lot of library research projects. Teacher 8 reported that his science teachers "mostly just lectured."

Only one participant, teacher 5, mentioned learning activities beyond lectures, scripted laboratories, worksheets, and library research:

> Marine science was really fun. I lived near the beach and so we got to do some stuff out there and that was really cool… We went out and did water quality stuff and then we of course looked at the type of flora and fauna that lived in that particular area (teacher 5).

However, this class also included traditional lectures:

> Q: So it wasn't the typical lecture?
>
> R: There was plenty of that too! But, at least we got to get out and do stuff, it was hands on (teacher 5).

Like high school, college science classes tended to be traditional, comprised of a lecture course with an accompanying laboratory section. "Mostly it was lecture and lab" (teacher 5), but teachers did report more hands-on activities. For example, teacher 8 did a lot of fieldwork in his geology classes. However, the nature of this fieldwork was more traditional in that the instructor scripted it: “He just told us what he wanted, and turned us loose, at this point. He’d say, ‘I want you to go out here and contour this area between these points’” (teacher 8). Unlike the other teachers and in contrast to his high school courses, teacher 1 found his college science courses mentally challenging: “There was a lot of emphasis on hands-on things, experimentation, asking questions.”

Three of the teachers, 1, 3, and 6, had science experiences in college or beyond, outside of science courses. Teacher 1 worked his way though college as a technician in the plant pathology department. He was given the responsibility of identifying the flora and fauna on a coastal island, which included finding and naming several new species. Teacher 3 participated in various research experiences during each of the three summers intervening between the regular long semesters. She initially started a career in her field but wanted a career that was more people-oriented and so switched to teaching. Teacher 6 worked during college in an animal research laboratory and interned as a zoologist after college. When teacher 8 graduated from college, there were no jobs available in his field due to a downturn in the economy. He decided to try teaching. When jobs in his field opened up, he worked as a corporate scientist for 5 years. However, when laid off again, he went back to teaching. Two of the teachers, 3 and 4, worked as teaching assistants for introductory science classes.

These findings illustrate that teachers’ experiences with school science were disconnected with the concept of culture. Consequently, it is not surprising that classroom observations of their teaching contain minimal referents from the students' culture. Put simply, it is not a practice with which they have personal experience as a student. In spite of this deficiency in preparation with regard to content, their training has given them insiders' knowledge about the pipeline to science-based careers. Although not all of them pursued careers in science before becoming teachers, they all have experienced success in science at the college level and thus have valuable knowledge to pass on to their students who may desire a science based career.

Interpretation of "Science for all Americans"

"Science for all Americans" arose out of science education reforms of the 1990s and characterizes the American Association for the Advancement of Science (AAAS) current goal for science education and is consequently a *de facto* mandate for K-12 science teachers. The goals of these reforms are to provide education for today's students that will prepare them to be full participants in a global society that is increasingly more scientific, mathematical, and technological. None of the teachers referred to these reforms when discussing this phrase, although five of the eight (1, 3, 4, 5, 6, and 8) and had been trained after the book, Science for all Americans, had been published (American Association for the Advancement of Science (AAAS), 1989). One of the participants stated that the phrase sounded "like a politician's dream" (teacher 7).

In their responses, several of the teachers included the idea that science connects to life outside the classroom. Teacher 1 stated, "Because science is such an important part of our lives, in our culture, all Americans experience an impact from science on a relatively frequent basis, whether they know it or not." He went on to explain that he tries to get them to see science in their daily lives. Teacher 4 held the same view, "For anyone and everyone, here in America, regardless of your legality. I mean if you're in America, you're bound to encounter anything…metric system, measurement…" Teacher 6 extended this idea in her response:

> All Americans coming out of the school system would end up with some level of scientific literacy, which doesn't necessarily mean knowing parts of the cell or knowing, you know, physical equations. It means, more, just being able to think critically. […] And not just science, but that can kind of carry over into other areas of your life.

Teacher 3 interpreted "Science for all Americans" as a usable knowledge base about which everyone agrees and has access to.

In order to show how school science extends to non-school life, some of teachers interwove real world topics in their science lessons. For example, in one lesson, as part of learning about cellular differentiation, students in teacher 1's class were gathering information for an upcoming debate on stem cell research. Part of this gathering included Web searches for recent articles on the topic. Teachers 5 and 6 included discussions or debates on genetic engineering when students were learning about genetic engineering. Topics were all from the teachers' world, not the students.

Another interpretation of “Science for all Americans” was developing the ability to think critically or evaluate scientific information students might encounter (2, 6). For example, Teacher 2 said that, “All Americans should be able to know and follow the scientific steps to solve [life] problems, if they want or choose to.” Teacher 6 said that she wanted students to be able to understand the nature of scientific information they might encounter in daily life, “what does a scientific conclusion mean and where does it come from? And kind of being able to look at scientific information…understand that it’s not fact, and just be very critical in the ways they look at things.” Both teachers 2 and 6 modeled critical thinking. In teaching about waves, teacher 2 demonstrated reflection and refraction of waves on a heterogeneous string; each half of the string was made of a different material and had a different mass. The lesson was constructivist in that he continually asked the students what they observed, asking them to describe what they saw happening. As the class proceeded, he began to diagram the resulting wave patterns on the board, teaching them about behavior of waves at interfaces. His questioning of the students directed them to consider what they had seen with their eyes and what that meant, given the scientific concepts he was teaching them. Teacher 6’s teaching was a similar semi-Socratic, rhetorical style. During a lesson on genetic disorders, groups of students were researching answers to questions. I saw her follow an instructive sequence when working with groups who asked for help. She first asked the group to clarify what they were looking for, what they had done to find it, and what they had found. She then asked them what they thought they should do next. One group of students responded that they didn't know. Teacher 6 told them what to do. This was repeated several times as she moved to different groups. However, with one group, she didn't respond immediately; after a few moments of silence, several of the students gave responses all at once. She nodded her head and walked off. Both teachers used methods that modeled critical thinking. However, neither made explicit connections to scientific thinking about the given topic or concept in a real world context.

Teacher 5 and 7 didn't mention the idea of science beyond the classroom; "Maybe that all Americans should have some grasp of science and its concepts" (teacher 5). Teacher 8 responded, "that all of my students got the same degree of instruction." He also mentioned equal access to equipment such as calculators and computers. This concern for equal access to resources is a positive aspect of this categorization. Ironically, in speaking about his teaching and in practice, teacher 8 treated regular and honors students very differently. For example, in an honors class, teacher 8 gave students a traditional lecture on the structure of the atom. This lecture included discussion of early experiments that showed the development of thinking, such as Rutherford's gold foil experiment, that is, students in the honors class were given some conceptual underpinnings of the structure of matter. In a regular section of a class on the same unit, students were doing flame emission tests of transition metals, demonstrating periodicity of the elements. Teacher 8 told students what they would do and observe and what it meant, but without the same elaboration of conceptual understanding as the honors class.

Taken as a group, teachers' ideas about how to meet the AAAS's goal of preparing students for an increasingly scientific, mathematical, and technological society (1989) are limited. Several mention ideas that would be part of this goal such as connecting science to everyday life or developing critical thinking. However, their enactment of these ideas is through content that is peripheral to the subject matter, such as measurement, rather than central to it. A comprehensive understanding about the role of science education in preparing their students for full participation in a global society was neither articulated nor demonstrated in interviews or observations. What was missing from teachers' characterizations and behaviors that would distinguish them as highly equitable were connections between students' home culture and science of the mainstream. However, given their prior experiences in school and science described in the previous section, this finding is not surprising.

External pressures on content

Choice of content is an important concern of equitable teaching (e.g., Ladson-Billings, 1995; Lynch, 2000; Moll et al., 1992). Science teachers in the district under study have two types of pressures with respect to the content they teach. The first one has to do with the discipline or institution of science. The concepts of science content taught at the high school level are established and agreed upon by practicing scientists. For example, it is unlikely that scientists would dispute that an introductory study of biology should include units on cells, microbiology, plants, and animals or that an introductory course on chemistry should include units on the nature of matter, interactions of matter, and energy. Documents guiding science instruction at the high school level such as the National Science Education Standards (National Research Council (NRC), 1996) and Benchmarks for Science Literacy (American Association for the Advancement of Science (AAAS), 1993) include knowledge of key scientific concepts as items every child should learn in science classes. Consequently, science teachers have this constraint on content.

Consciousness of this *de facto* curriculum infuses teachers' interview responses. In discussing a debate students had on stem cell research, teacher 1 says, "I want them to have the knowledge base and the information that they need to make decisions." In another interview, he continues, "I'm primarily a biologist, […] I want to be able to share what I know with the students." Teacher 6 described an assignment for which she has students analyze the scientific evidence justifying some commercial advertising. When asked how often she does this, she says, "Unfortunately, not that often because, content wise, it's really not…you know, except for the scientific method, it's hard to like, tie in." As mentioned previously, an important concern for teacher 8 is that students master the material. Teacher 7 discusses the same concern: "I haven't done my job if students don't know the basics."

The second pressure on teachers with respect to content comes from the political system. Both the state and the district administer science content tests to students. The district monitors teachers' adherence to the IPGs by administering tests every six weeks. The IPGs and tests have affected the teachers' implementation of content. When talking about performance-oriented instruction that he used to do, teacher 1 explained, “[The] IPG is such a driving force—some of this has had to go by the wayside.” Teacher 6 notes, “[O]ne good thing, I will say about the TAKS test. It has a lot of drawbacks, but the one thing is it really has given a sense of urgency, at least to me, in the level of the rigor and the level of questions I ask my students.” She goes onto explain that students need to know the information she teaches well enough to apply it in what she termed “multi-level questions” such as which bonds in DNA are the weakest. Consequently, she has changed the types of questions she asks. She explains,

> Textbooks don’t say, “The bonds are weakest here.” And they wouldn’t remember that anyway, even if you directly taught them that. So, even though I do assess with tests a lot, I really do try to assess with higher-level thinking types of questions and get them used to that.

Teacher 8 explains his thinking:

> You have to follow these guidelines [IPGs], and, basically, it was too short. It was too short a time to teach it. I had, like, two 6-weeks to teach chemistry. OK? And then all top of all that we had, you know, we spent a week preparing for TAKS, we spent a week taking the TAKS, you know. Then we have finals coming up, in all this, and there’s just not enough time. And I was just hitting the main ideas, points.

Teacher 4 taught her Limited English Proficient students in English, after considering that they would need to take the TAKS in English. She also acknowledged she encourages “accountable” talk in written assignments per the districts' IPGs. Like teacher 8, teacher 7 follows the IPGs. Several responses included the phrase, "I teach what's in the IPGs." Teacher 3 admits that students' test scores do affect what she does in the classroom. She explains,

> No matter what anyone tells you, people are competitive about the scores. I mean, it's not like they're posted anywhere but you hear talk about it. […] I definitely feel like I need to do warm-ups at the beginning of class—it means that we're not doing biology [during that time] but if you don't do it and your students don't do well…

This finding indicates that these teachers are conscious of their role as agents of the institution. They articulate that part of their role is to transmit the curriculum desired by the district and state. None of them question the role high-stakes testing plays in constraining their curriculum choices, nor the fairness or appropriateness of administering these types of tests to the students they teach. In fact, teacher 8 welcomes the curricular uniformity that testing brings.

The discretionary curriculum

As illustrated in the previous section, teachers felt constrained to teach the content prescribed in the IPGs due to institutional pressures. However, they did find time in their curriculum to teach additional things that they thought were important, that they were interested in, or thought could be taught better than the prescribed curriculum. Teacher 1 has students debate stem cell research because the ethics of genetic engineering interests him. Teacher 2 threads a theme throughout the entire year about how applying a scientific mindset can solve any life problems his students might encounter. During a lesson about stimulus-response, Teacher 3 spent a portion of lesson telling her students about a project she had done in college using electrodes to stimulate the mechanical actions in a heart. Teacher 4 says she regularly gives students assignments to do acts of service for someone at home and then report back about them. Teacher 5 adds water studies to his curriculum: "I like water, to talk about water. So, we spend a little bit of time on that, so hopefully, they've left, understanding that it's very, very precious and important and […] because that's what I enjoy." Teacher 6 adds a short unit on the ethics of doing animal research during the first semester of biology. In talking about using Cambridge Physics kits, teacher 7 mentions, "Chemistry is very lacking. I don't even use the chemistry aspect. I have my own stuff for chemistry just because it's very, very lacking in that regard." Teacher 8 stated that teaching some of the chemistry is difficult: "just because we had to create some of our own lessons."

In other words, although teachers do feel programmatic constraints about what they can and should teach, they feel enough freedom to make room in the curriculum to teach things they are interested in, feel are important, or decide to teach. This glimmer of flexibility to teach to their own interests indicates that there may be fertile soil for expanding these teachers' notions of curriculum to include framing their curriculum around the culture of their students.

Synthesis

The findings in this part reveal that teachers have had experiences that give them a picture of content that removes it from the social context in which the knowledge base of science was created. While all of the teachers acknowledge some aspects of subjectivity in science, they differ about the source of the subjectivity. One of the lessons I observed in teacher 3's classroom dealt with taxonomic classification. She mentioned how the kingdoms have expanded and talked about why. In discussing the class afterward during an interview on the nature of science, she said,

> There is a subjective aspect to every theory and it changes as new information comes out, of course. For example, we had one type of kingdom system that's changed, who knows how many times. And with new DNA sequencing, things that we once thought were related, now we know they're not related at all.

Other teachers had different explanations for the subjective nature of science. Teacher 2 said, "Science and scientists are part of the culture in which they live." However, he then went on to say that because the development of scientific knowledge is tied to "observables," there is also an objective aspect to science and scientific knowledge. Teacher 4 and 7 explained that subjectivity in interpreting data could be due to personal biases, learning, and life experiences. Teacher 5 talked about supporting conclusions. He said, "So, research can support [conclusions]…but it can be manipulated also. You can find information if you want to prove something." Teacher 6 talked about why she showed a video on the 1989 oil spill in Alaska. In the video, Exxon scientists and Greenpeace scientists come up with different conclusions about the impact on the environment. She says, "Scientists are supposedly looking at the same stuff but their conclusions are completely different. So, you know, science isn't perfect. It doesn't give us hard fact answers, very often." She taught this same idea to her students during discussion of the video. Although many of her assessments include right and wrong answers, teacher 6 also includes more open-ended assessments such as debates, presentations, and concept maps, in which there are multiple possible answers. Teacher 8 acknowledges, "I do know that science is affected by religion and politics, quite often, you know, like in the choosing of textbooks, and things like that." He elaborates that religion and politics also causes "a big clash […] in terms of what we study; how we present biology and evolution, who knows." Teacher 8's teaching reflects his ideas about subjectivity: in the classes I observed, all questions, procedures, problems, etc., had what he would say were clearly defined right and wrong answers.

In spite of understanding that there are subjective aspects to science, none of them are able to transfer this understanding into creating curriculum that teaches content through the context of students' home cultures. It is likely that their traditional experiences in science, their narrow understanding of "Science for all Americans", and their belief in how to best prepare students for success on standardized tests limit their ability to see that they can teach students the content necessary for future success in science using a culturally relevant context. However, their freedom to enact curriculum of their choice, discussed in "The discretionary curriculum" indicates that teachers may be willing to create curriculum using cultural referents as the foundation, if given sufficient training and motivation.

Behavioral and relationship oriented strategies

In this part I present themes about teachers' behavior and relationships with students. Generally, teachers behave in ways that align with the strategies suggested in chapter 2 in that they use inquiry based teaching, know and care about their students, act as role models, and structure the learning environment.

Characterizations of teaching roles

During the course of the interviews, the language and expressions teachers used served to characterize subtle differences about their views of their role in the teaching relationship. Teachers 1, 2, and 3 are labeled parents. Teachers 4, 5, and 6 are role models. Teachers 7 and 8 are institutional agents. A summary of these categories and a few sample statements are given in table 4.1. The parents group comprises teachers whose language implies they see their role as nurturing or fostering with the intention of actively shaping the attitudes, dispositions, or life outcomes of their students. The role model group comprises teachers who describe themselves as role models for their students due to similarities between their life experiences and those of their students. The institutional agents group comprises teachers whose language implies they limit their role to carrying out their function as employed teachers in the district. Although all three of these teachers expend time and efforts to help their students learn, their descriptions are consistent with the concept of institutional agent.

Table 4.1: Conceptual categories of teacher-perceived roles

Teacher	Statements
Parents	"For many of our cherubs" "What I try to teach my kids" "I just have to push them along a little bit" "I provide them with answers, and guidance"
	"I think at their home their parents do not take care of them much. They do not know that side of their emotional needs. But as a teacher, you know." "Subject to me is just a tool so that you can teach, to develop the mind of the student as well as you go along with the student for their emotional needs." [Role is] "Partly as a parent."
	"I'm very blunt about the consequences of their actions and tell them getting pregnant is stupid." "I despair over my kids…"
models	"I'm just like, 'Hey, look at me.'" "That's how I draw from my personal experiences to help teach and show them."

	"I just hope I'm strong enough […] to be able to model to […] these kids." "You know I tell them…be who you are, and understand that and work from there." "I tell them that I was a poor student when I was in high school and it can be done and it's important."
Institutional Agents	"I try to help them with, like organization and management skills." "There's also content that you have to really work on." "Well, with a 150 kids, it's hard to really do more, much more than just…" "I stress how important the assignments are to them. I give them updates on their grades every week so they can see where they are and see what they're missing."
	"I teach to the middle." "I don't know any of my students personally or well enough to discover their life experiences." "Parents usually initiate contact and then I'll follow through."

“All of my students get the same degree of instruction. They each get a calculator, access to computer.”

“The more years you teach the better you get.”

“Discuss the lab the day before, that is considered part of the lab. And then wrap it up the next day, give a quiz, and we go over the quiz, and the departmental post-lab. So, I guess I should say that we really do 40% if you include that. So we cover ourselves, and it is legal.”

All three of these categories have both positive and negative aspects. Parenting is a positive concept when it indicates nurturing, care, concern, and efforts to facilitate growth into mature, self-determining adults. However, it can also be negative if intentions are patronizing or purposely place the learner in a subservient position. Similarly, role models can be inspiring to learners, showing a potential pathway for emulation, but they can also disintegrate into cults of self-adulation that prevent the formation of warm and genuine relationships of caring. Recall from the literature review that some researchers critique the highlighting of role models in science, as they suggest ethnicity correlates with a single, generic culture. Institutional agents appear to replicate the existing power structure without questioning the validity of power relationships. However, in a positive light, institutional agents work to give students the tools of the existing power structure, such as the knowledge base and skill set of practicing scientists. With these tools, students can be empowered to make science (and society) more equitable.

These three categories arose from a holistic interpretation of the data. In contrast, teachers were asked to conceptualize their teaching by describing it through a metaphor. Teachers, 1, 6, and 7 could not or did not identify metaphors for their teaching. Teachers' 2, 3, 4, 5, and 8 metaphors are given in Table 4.2. Teacher 2's

Table 4.2
Teachers' metaphors

Teacher	Metaphor
2	My teaching is like "reading a comic". That is, easy to understand and follow.
3	I see myself as a teacher of reality more than a science teacher. It is a daily battle to get kids to look at themselves. Some agree to change and then my job is fulfilling. It is kind of full of ups and downs. I'm a little boat on a big ocean.
4	A keeper of the garden, not necessarily the one who planted these kids but tending to them so they are growing in the right way or making sure that they're strong and healthy and upright, mentally, you know. And just tending to that and giving them the proper nutrients that they need so they can sink their roots in deeper and grow stronger and not be yellow-leaved and dry from neglect.
5	A Tree—I try to be strong and consistent, but flexible enough to allow students to be themselves, or comfortable. My teaching hopefully also promotes growth in respect to students in that the environment of the classroom is open and welcoming, with few conditions.
8	I'm like a sponge, constantly absorbing new information to later share with my students.

teaching method agreed with his explanation of his metaphor in that is general teaching style was “clear explanations”. During each of the lessons I observed, he taught the content by asking carefully sequenced questions. By answering these questions themselves, he expected students to construct scientific knowledge. Teacher 3’s explanation likewise agreed with her response to the metaphor question. In one of the lessons I observed in her classroom, students were constructing sequences of DNA out of paper or gumdrops. Although there were side conversations, all of the students were engaged in constructing DNA sequences. As I went around to the different groups, students were able to explain the linkages of the different groups of atoms. After the class was over, I talked to teacher 3 about the level of engagement. She agreed that students were engaged in this class but not so much in her other ones. However, she couldn’t say why this class was “better” than some of the others. This observation and reflection support the explanation of her metaphor as being full of ups and downs.

Generally, these teachers teach fairly traditional content in teacher-centered ways. All of the teachers have students do labs, but these labs act as supplements to lectures and worksheets. All of them use inquiry type of activities. Several of the teachers have students do constructivist-type projects (3, 5, 6, 7, 8), but these projects are teacher-directed in that the teacher defines questions to be answered or problems to be solved, and provides the resources or activities through which students can answer these questions or solve the problems. None of the 40 lessons I observed had students finding information to questions of their own choosing.

Additionally, all 40 lessons would be included under the umbrella of Western science. In other words, their teaching methodology is most consistent with the institutional agent orientation to teaching. However, considering that the goal of equitable teaching identified in this paper is increasing the participation in science of underrepresented groups, teaching the knowledge base of science is consistent with this orientation regardless of the method used to teach it.

Assessing content knowledge

Teachers mention a variety of assessments to ascertain how well students are learning this content. All teachers mention informal assessments such as listening to them talk to each other (1, 2, 3, 4, 8), calling on them during lectures (2, 7, 8), and observing during lab or group work (1, 2, 3, 6, 7). For some units, teacher 6 has students give presentations. Teacher 6 also uses pre and post concept maps. Every teacher uses traditional pencil and paper work such as worksheets, reports, quizzes, and tests for determining grades. Teacher 5 explains, "Of course we are forced to grade. It would be nice to have the time to really get into each and every kid, but that is tough." Teacher 4 mentioned that having a lot of students prevents her from using alternative assessment for all grading. She explains:

> The best thing for me if they can teach me, right back, or if they can teach someone else. I do a lot of cooperative learning and I monitor all the groups…I do a lot of listening. A student can write it, as well, but it means a lot more to me if they can tell me, in their words. I have some students who aren't comfortable writing and so I'll let them tell me. I also do formal

> assessments—pencil and paper. But, I would much rather see them “do it”. It’s hard not to use traditional pencil and paper but I really want to hear them…make connections and be able to teach the concept…comparing and contrasting ideas…that’s what shows me that they’re learning. I use traditional pencil and paper, fill in the blank, choose the right answer. We have to do a lot of assessment that way. The traditional benchmarks, and testing and all of that is still there but what means more to me, is not going to have any value to the district or the state but what means more to me is to hear them talk about it. “That is this and I know that because…” or, just little things like that shows me that they’ve understood.

Perusal of posted grading sheets indicated that grades were based on tests and assignments. Several of the teachers did include “participation” as a category, but there was no apparent vehicle, such as a rubric or daily participation grade, through which this part of the grade was assigned. Generally, teachers’ assessments are consistent with their conceptions of content in being focused on assessing students’ ability to reproduce the content taught in class through traditional tasks. Teacher 6 is the only one who incorporates alternative types of assessments in her grading scheme.

Given the ubiquity of traditional assessments, such as statewide standardized testing, along the pipeline to a science based career, these teachers’ means of assessment falls in line with the conception of equity as preparing students for success along pipeline.

Deficit model teaching

Teachers generally have a negative view of students' preparation for science. Teachers discussed their students' life experiences throughout all three interviews. Uniformly, teachers identified negative aspects of students' lives.

All the teachers described some of the students as being poorly prepared as illustrated in these excerpts:

> Most of my students seem to be graduates of the "do the least I can get away with" school of social and educational rearing. Many (can't quantify but more than a quarter) are unable to read at grade level and, what is most discouraging, are unwilling to extend themselves to improve the deficiency (teacher 1).
>
> They need attention, a lot of one-on-one help. They're, for the most part, they're pretty lacking as far as the basic skills. They come here with very low reading levels, a lot of them; limited English…just needy in a variety of ways, really. I'm not saying they're all like that, of course, but I would say a high proportion of them are. Very low math abilities for the most part (teacher 8).

Some of the teachers (1, 3, 4, 6) cited previous educational experiences as part of the cause for this deficiency.

> [W]ith students who aren't motivated, who aren't willing to put forth any effort. And probably can't read very well, because, it started, probably for these kids, when they were much younger. And they didn't get a good

education in elementary school. […] So, the majority of students who end up sitting around in our courses, and don't do anything, and act like they don't care about school, are the kids who, really, probably can't read very well, and have very low math skills (teacher 6).

Teacher 3 said, "We're basically too busy trying to catch up with things the kids are supposed to bring from middle school anyway but they don't." Teachers also cited familial dynamics or characteristics as sources of poor preparation (1, 2, 4, 6, 7). Following up on her previous statement, teacher 6 said, "Maybe they had family problems, maybe their parents weren't, didn't practice with them, whatever." Teacher 4 noted, "A lot of these kids grow up and they have no print at home. It's not print-rich." She elaborated that since her students don't see adults reading in the home because there are no books, magazines, or newspapers, poor reading skills are not surprising. This observation about what students are exposed to at home is consistent with her role model orientation to teaching. Of the teachers who identified home life as a possible source for poor preparation, teacher 4 was the only one whose comments didn't sound like a criticism. In talking about print, she mused, "The only print they know is McDonald's. And that's fine, at least they're getting some awareness even if they don't have print at home." Teacher 4 was the only one who had positive comments about students' lives. For example, at one point, she elaborated on a student whose parents were illiterate. In spite of being illiterate, the parents stressed the importance of schooling to their daughter, who is GT in English.

This view of students influences teachers' behaviors. In order to make up for what they perceive as poor preparation in their students, several teachers (1, 2, 3, 6, 7) make the learning environment as structured and clear as possible. For example, teacher 1 said, "I try to set clear goals for all our work and try to explain the steps to goal achievement in detail." Teacher 7 said, "At the beginning of the year I establish a routine for everything…handing in work, getting [lab] equipment…anything that they do in my class, there's a routine for so they know what to do and what I expect of them." Her class is well ordered without being oppressive. The assignments for the week for each section are posted on a side chalkboard. There is an inbox for assignments and folders for individual sections where students pick up graded work. Current scores and grades are posted on the wall. When asked about making up deficiencies in preparation, teacher 2 suggests, "Understand and memorize the key concepts from front to back." At the beginning of class, teacher 7 gave precise, sequential instructions about the worksheets students should fill out, the order in which they should be filled out, and what calculations should be done. Teachers 3 and 8 address perceived deficiencies in preparation primarily through re-teaching what students should already know. At the beginning of each unit, teacher 3 outlines and reviews prerequisite skills and knowledge necessary for success. Teacher 8 explains, "[I go over] reading strategies, review math concepts at the beginning of the year."

Teachers use a variety of behaviors to help their students be successful in their courses. Teachers 6, 7, and 8 said that they encourage students to make up missed work or redo work that wasn't done satisfactorily. During interviews, teachers usually had at least one student making up work in their classrooms. All of the teachers mentioned using analogies and everyday examples to help students understand. All the teachers were observed using these strategies. Teacher 3 had students do a lot of visual work. For example, in a lesson I observed about stimuli-response, she had students drawing Venn diagrams. In another lesson, students were creating concept maps about disease. Additionally, her room was full of construction paper projects that students had created to visualize concepts. Teacher 4 used a wide variety of learning strategies including visual representations, reading, lectures, problem-solving, and hands-on work. In addition, she had students working in groups during all of the observations I made.

One of the issues that teachers brought up repeatedly dealt with the problem of communication. Teachers 3 and 6 noted that students generally have a very poor vocabulary. Teacher 6 says, "We do work on vocabulary and expanding it in a usable fashion." After observing a lesson on cell biology that included the introduction of a lot of new terms, teacher 6 observed that biology at the high school level probably required students to learn more new words than they would in a foreign language class. Teacher 2 thought students' poor reading skills prevented them from being able to understand the textbook. Consequently, he didn't think it was useful for them to have "book study" time during class, a common practice at his school. Instead, he taught students the concepts they needed to know through discussions, explanations, demonstrations, and labs. Teacher 1 noted that his students couldn't read at a level sufficient to understand the newspaper. To address this perceived deficiency, he says, “I require that every answer a student presents to me, in a formal way, written materials, answers to quizzes, be couched in a grammatically correct English language sentence.” After making this statement, he spontaneously brought up the topic of students whose first language isn’t English. He said, “My Spanish-language primary students have a lot of leeway. They can respond in Spanish but it must be grammatically correct, correctly punctuated. I speak a little Spanish and read more.” Teacher 1 makes some observations about the education system:

> We are, while not forbidden, discouraged from providing those kinds of assists to our English language learners (ELL). I think that will change with the new textbook adoption, publishers are providing more Spanish language materials.

Teachers 1, 4, and 8 are the only ones who specifically talk about students whose first language is Spanish and who are not yet proficient in English. Teachers 1 and 8 say they pair up students who are learning English with students who speak Spanish and English. Both of them feel this strategy has been successful. Teacher 1 explains, “One of my best students is doing virtually straight-A work with those strategies. She’s got a good friend and the friend reads and speaks pretty well.” Another strategy teacher 1 mentions is working closely with the English as a Second Language (ESL) teacher. He says,

> At testing time, [I] provide a copy of the test to the ESL teacher and the students are permitted to go with their test to the teacher, during the

conference period, to take test in presence of Spanish-speaking teacher who can translate the words.

Teacher 1 also mentions giving ELL extra time to finish assignments.

Other than teacher 8's comments about ELL, teacher 1 was the only one to explicitly single out groups of students and make generalized statements based on family culture. He explains,

> [B]eing away from the school is not an option unless they are, in fact, really sick. Part of this is the family perception of school, again. I can't give specific numbers but I've got at least 10 students in my four biology classes that make relatively frequent trips to Mexico with their family, just because they want to visit family. And of course, family's important and no one will argue that and therefore trips to Mexico are more important than being in school, and therefore, they're not in school.

Although not specifically mentioning a group of students, he also notes:

> They don't attach a great significance to being in class on time. Because, again, you can't socialize in class. That's what the passing period is for—you meet your friends and plan what you're going to do or discuss what you did. And, they resist all the strong clues that we give them that, hey, their perspective is wrong…that we do expect them to be in class.

Teacher 8 also mentioned problems with absenteeism but didn't attach it to any particular group. If students miss work in his class, they can make it up during Friday morning office hours or on Saturday school. Teacher 8 has found that Saturday school has improved his students' performance but cautions,

> But one of the problems I see with that is kids want to come and see those teachers who they're familiar with so it's mostly my kids, you know. I'm sure if it wasn't me here on Saturday, like if it was Mrs. XXX or something, it would be her kids coming instead of mine. So that's just one drawback there, that would get more kids of [other] teachers.

Although teachers have a deficit model of students, they try to teach them enough content to be successful in the course and on local and district exams. In other words, they don't assume that students are incapable of learning the content and teach them a grossly watered-down version of it. They give them extracurricular opportunities for help and to show mastery of the material. By giving students access to the knowledge base of science through their teaching, these teachers are promoting the type of equity targeted in this study.

Operational caring

Through interviews and observations, all of the teachers in the study give evidence of an attitude of caring for their students. For example, in setting the first appointment with teacher 1, he cautioned that our interview might be interrupted or postponed if he had students come in for help because they always came first. In a phone conversation, his wife shared with me that several times each semester he stays up all night to write thorough feedback on written assignments. His manner exudes warmth and concern as he relates anecdotes about his students. Throughout his interviews, reflective statements indicate that he has thought about his students' lives in terms of where they have been and where they are going; he tries to be a positive force in helping them on their way. For example, when asked about how he motivates students to participate in the education process he says,

> This is where I and the district differ a little bit. I feel it is not reasonable, wise, nor fair to adopt the policy that all of our kids are going on to college or should go on to college. I think we have to address the reality of the situation that for many of these kids, if they graduate from high school, they're going to be the first of their family, going back generations, that has done so. It's an incredible step. And if they decide to go on, that's wonderful. But to continually talk to the students about going onto college and preparing for college, I don't think is reasonable and I think it is counterproductive. So I adopt the point of view and try to keep this as my focus when I talk to them that living is a continual learning process. Life has got to be a continuous learning process. This happens to be a formal part of it to get them ready for whatever else is going on and many of them will undoubtedly go on to additional education at college or community college or vocational college, whatever; it's education, nonetheless, and it should continue all their lives but I really have a problem with the concept that all kids need to be prepared for college. In an ideal world with students with different backgrounds than many of our cherubs possess, then that would be OK. But you've got to play the hand you're dealt and for many of my kids, and I just speak of my kids,

> OK, because I can't address what other teachers are doing but for many of my kids, they have other priorities right now. Those priorities may change and I acknowledge they've got other priorities. For many of them, their priorities include getting out, getting to work, and getting out of the house. Now that's a sad, sad thing. But again, it is, it's their life, they're the ones that know and they're the ones who have set up the priority of getting out of the house is a big thing, for whatever reasons. I'm not addressing that, that's their priorities.

Teacher 1's disposition to put his students first, even to the point of staying up all night, and to consider how to best support their life goals, is consistent with his parental orientation to teaching.

Like teacher 1, teacher 2 has considered the effect of education on his students' lives. He cares deeply about their futures, which he believes will be vastly improved if they develop scientific minds. He talked a lot about his experiences about being first a teacher and then a principal in a low-performing school in his home country. He said when he first started teaching he didn't believe that the students would ever be high achievers. However, through applying strategies he read about in US education research journals, he saw students' knowledge level, attitudes, test scores, and behaviors improve. He expressed frustration with his experiences teaching in the US. He explains, "I think the problem here [in the US] is the teacher cannot instill what is being researched in the university in the classroom. Therefore you cannot see the educational theory in action in high school." He discusses strategies he used to cause positive change in his students abroad, “The students are in charge of the leadership project. You give them responsibility. You teach them how to.” He continues discussing problems with US education, “But they don’t believe that [here in the US]. Therefore they create more and more [controls]…according to the political philosophy…closed campus, to control them more. That’s the problem because when they go into society, it’s not like that.” He believes that developing a scientific mind in students helps them develop into emotionally well-adjusted, competent adults. During one observation, two girls sat in desks on the side of the room but did not participate at all in the lesson. Later, teacher 2 explained that he let them stay in his classroom during free periods because otherwise they would hide in the bathroom. During all of our interviews, there were students in the classroom doing work at the desks or working on the computers. Like the two girls, teacher 2 said the students came to his classroom because they didn’t have anywhere else to go. Rather than spend planning periods in his office, teacher 2 stayed in his classroom in order to give students a safe place to be. Consistent with his parental orientation, teacher 2’s classroom became a home at school for his students, a place to relax, share, and get help and encouragement.

Teacher 4 spent a great deal of time discussing the power of education in the lives of students as illustrated in previous quotes about choice. She related more personal anecdotes about her students than any other teacher. When asked why finding out about her students was so important to her she said, “So that I can understand the students and their learning styles, what makes them tick and what makes them explode.” She also mentioned effect of life experiences on learning:

> I want them to feel that it’s OK to come to school and talk about things. So, if we can get that out then they’ll be ready to learn. You know, because otherwise, if a kid comes to school hungry, or he just got yelled at for not cleaning the kitchen before he came to school, he’s going to feel bad.

In another interview she explained,

> I ask them about home, and I ask them about parents, and work, and, you know, and they’ll just disclose that information. I don’t try to prod or pry too much but if they’re willing to share it, they will.

Teacher 4’s classroom atmosphere matched her rhetoric. Although science teaching was the major focus of the observed lessons, teacher 4 talked to her students continually before class, after class, and during group work. Students came in and spontaneously shared what they had done in earlier classes, what had happened yesterday when they went home, what they were doing for the weekend, and other small talk about their lives.

Teachers 4 and 5 see similarities between their life experiences and those of their students. Both tell their students about their lives, reassuring them that they [the students] can overcome their hardships. Teacher 4 elaborates:

> I felt like I could really understand them and just say, “You know, just because these things happen to you, doesn’t mean that you have to stay there,” or, “It doesn’t mean you have to stay there forever.” […] I tell them a

> lot [about myself] because I want them to know that they can do it, you know. And there's hope, and they have options, and I know they can do it.

Her practice of telling students about her life is consistent with her role model orientation to teaching. In addition to building personal relationships with her students, teacher 4 believes that students will be more engaged in learning if their parents are involved in their schooling. Consequently, she expends a lot of effort to involve parents in the classroom:

> I feel like I really need the support of the parents, and the kids need their parents' support. So, if they're involved, then the students are going to realize that education is important. If their parents take an active role in what they're doing, then the kids are going to say, "Hey, school is probably important if my parents really care what I'm doing in school."

Teacher 5 continually talked about sharing his life with his students, illustrative of his role model orientation to teaching. In all but one of the lessons I observed, at some point in the lesson he talked about something he heard on the radio, typically from National Public Radio (NPR). For example, during a lesson on water quality, he mentioned a news story he had heard about Glen Canyon dam. Teacher 5 describes another aspect of his teaching, "I feel like if I can be positive and supportive, it just might be what some of them need to help them be successful." I also observed him talking to a student one-on-one about a missed test; teacher 5 discussed possible options for making it up. Although not excusing the student's behavior, teacher 5 stressed to the student that he hadn't "blown it".

Teacher 5 and 6 both felt that they could do a better job finding out about their students on a more personal level. Teacher 6 expressed:

> Sometimes I wish I were more aware. We have these team meetings at my school where we meet with all of the 9th grade teachers and the counselors and that helps because sometimes I can find myself being like, really, "You didn't do you homework!!!" or just being really mad and then, you talk to the counselor and you find out their parent died or, like maybe they're, a lot of our kids, I mean, just this year we've had kids whose parents are getting a divorce, their dad's an alcoholic, their dad's in custody, or just all kinds of stuff like that. So, it really helps you be a little bit more, kind of aware of their circumstances and help them out.

However, she adds:

> I don't know that it changes my instruction in the classroom at all, because I still have 150 other kids to deal with but, trying to be, like, on a case-by-case basis, listen to what they have to say and… Obviously, if they're always having a crisis, that's not good, but, you know…

Teacher 6's institutional agent orientation slows her from acting as an agent of positive change in the lives of her students.

Teachers notice the emotional states of students on a daily basis. Teacher 1 observes, "It's really easy to tell when a student has something really big on their mind. It doesn't take much to say, 'Hey, how's it going, anything I can help with?'"

Teacher 2 relates several anecdotes about responding to students' emotional states. For example, during one interview he says,

> Yesterday, I had a student here who was not feeling well. I say, 'you should be happy because you're going to have a baby.' She's in my office and I tell her, 'You are feeling unwell because of the baby inside.' And immediately she brightened up."

Teacher 3 shared,

> These kids have tough lives. I know I can't do everything for them but I think they know I care and I think that makes a difference. They haven't had too much consistency in their lives so I try to be an adult they can trust. If I say something, they know I mean it. At the beginning [of the year] some may try to push the boundaries but they learn pretty quickly I'm not going to budge on most things. […]

This comment reveals a positive aspect of her parental orientation.

In describing being from a single parent home, teacher 4 says, "I understand that these kids are home alone a lot. I understand that they feel just kind of lonely sometimes and they want to know…and I knew that my mother cared for me but she was working, and she had to." Teacher 5 notes, "I mean, they're just like me, they have problems and issues, hardships, just like we do, as adults, ranging from being fine and then just bursting out crying. That actually happens, you know." Both of these comments illustrate teachers 4 and 5 consciousness of the orientation of teachers as role models. When talking about her role, teacher 6 states, "Especially in the regular class, they tend to get, like, tired or, frustrated, or just want to put their head down and say, ‘Forget it.’ So, just going around and encouraging them to try and do their best.”

Two of the teachers, 7 and 8, made no comments nor shared anecdotes about students’ emotional states. In my observations, their classrooms were not unfriendly places. Students bantered with both teachers about non-school questions, such as about their weekend and evening activities and whether or not they had seen or were planning to see a particular movie. During small group work, teacher 7 asked a student how he was doing in a math class. I don’t think that teacher 7 or 8 were unfeeling towards their students. For example, both expressed interest in student learning in that their students would learn enough science to do well on the TAKS test. Rather, it did not seem to occur to them that creating a relationship of caring was within their purview as a teacher, an attitude that reveals a negative aspect of their institutional agent teaching orientation. In addition, after several of the observations, teacher 7 made comments about particular students in the classroom. The majority of these statements concerned transitioning of behavior and teacher 7’s response to it.

<u>Participants’ beliefs</u>

As revealed in these findings, teachers have varying beliefs with respect to content and behaviors and relationships. Possibly categorizations for where teachers might fall on each dimension are illustrated in figure 4.2

Figure 4.2: Teachers' placements on content and behaviors continuum

Least equitable — Most equitable

CONTENT		
Low-level	High-level	High-level & engaging
	1-8	
BEHAVIORS AND RELATIONSHIPS WITH STUDENTS		
Alienating	Culture generic	Culture specific
	1-8	

All of the teachers fit into the continuum under high level content because they all try to teach the prescribed curriculum in order to promote high achievement among their students. Even within this categorization there is variation. For example, teachers 6 and 8 talk about how they make their honors classes more challenging than regular level. However, since both of them enact curriculum designed to enable their students to pass the TAKS, they remain in the high-level category. In spite of their placement in the high level, none of them use the content as a way to engage students and interest them in a career in science. Consequently, these teachers' characterizations of their practice and manifestations of these characterizations fail to fully incorporate the content-related equitable strategies detailed in chapter 2 while being consistent with the definition of equity leading to increased participation in science of underrepresented groups.

All of the teachers fit into the continuum under culture generic: while they do not utilize the culture of the students as a vehicle for conveying content, they also do not try to erase students' culture as would be prescribed in assimilationist-type methods. Like the dimension of content, there is variation within teachers' culture generic behaviors. For example, teacher acknowledges students' right to self-determination when he talks about their choices of avoiding college in order to establish financial independence. However, he makes it clear he doesn't value this choice, nor does he explore extenuating negative circumstances that might lead students to these choices. Teacher 4 works hard to not invalidate students' home culture as shown in her remarks about hitting but doesn't actively promote the development of cultural identity. Teacher 5 actively promotes students' pride and respect for being Hispanic. Teacher 8 doesn't actively engage in assimilationist behaviors but may reveal these tendencies when he talks about the nature of facts.

Summary

In general, these teachers articulate sincere intentions about trying to do a good job. They understand that success in school is important. They understand their role in helping students perform well on gate-keeping standardized tests. They want their students to learn; they are aware that many of their students aren't learning. Several teachers reflect on why students may not be learning, offering the domino effect of early school failure or success or parental involvement as possible explanations. However, none of them are implementing the equitable practices with regard to culturally relevant curriculum identified in Chapter Two. In Chapter Five I offer a way of looking at this discrepancy that respects teachers and what they bring to the classroom.

CHAPTER FIVE

DISCUSSION AND IMPLICATIONS

In the first part of this chapter I answer the research questions using the study findings from chapter 4. In part two, I compare the strategies and attitudes of participants with those advocated by the literature. The third part of this chapter comprises implications from this research.

Part 1: Answers to research questions

Question 1: How do secondary science teachers in culturally diverse classrooms characterize their teaching practices with respect to equity?

a. They characterize it as providing a role model.
b. They characterize it as acting in loco parentis.
c. They characterize it as providing clear instructions and a well-structured environment.
d. They characterize it as providing extra help, extra time, and opportunities for students to redo work.
e. They characterize it as teaching content consistent with the district IPGs and that will enable students to pass the TAKS.

These characterizations provide a pedagogical foundation, which could lead to increasing participation of underrepresented groups in science-based careers. Half of the teachers (1, 3, 6, 8) have been members of the community of practicing scientists. They bring an insiders' insight about the knowledge and skills students will need in order to be successful in science based careers and all but teacher 8 actively transmit this understanding to their students. They actively model and would like to promote behaviors characteristic of science such as critical thinking and evidence-based reasoning. Since they are currently teachers rather than scientists, they aren't contemporaneous role models. However, their pasts stand as examples for students to follow.

In the role of parent, all of the teachers are concerned with providing the tools students will need to successfully navigate the next gate in the pipeline to a science-based career, such as the knowledge and skills necessary to obtain good scores on standardized science tests. They provide these tools by creating environments that they believe enhance students learning. They give students additional time and support to attain these tools.

Ideally, teachers' characterizations of their practice should align with those strategies advocated in the literature cited in chapter 2. Although teachers' deficit views of their students, which lead them to behaviors such as giving extra time to complete assignments and opportunities for makeup work, are in direct contradiction with the conceptual foundations of these strategies, nevertheless, their characterizations of themselves as role models, parents, and classroom organizers provide a foundation upon which professional development designers could build effective programs for assisting these teachers in making their practice more equitable.

Finally, teachers' concern for teaching the content is consistent with the model of equity defined in this research. If students are going to be participants in the community of scientists, they must first master the knowledge and skills that will prepare them for academic success in college level science courses. These teachers are interested in helping students achieve mastery.

Question 2: How are these characteristics manifested in their classroom practice?

a. They are satisfied working in diverse environments.
b. They know and care about their students.
c. They choose content based upon the IPGs, TAKS, their interests, their beliefs about students, and their own knowledge about science.

None of these teachers articulate views that would imply an interest in maintaining the existing power structure. Their enthusiasm for teaching, the relationships they have built with their students that give them knowledge of their home lives, and their conscientiousness in teaching the knowledge students will need in order to be successful in science based careers, imply an interest in opening up the pipeline to participation in science to their students. However, they seem to lack the knowledge and skills in order to do so. Like their characterizations that comprise the response to research question 1, these teachers' classroom practices provide a solid foundation on which to build professional development programs that promote equitable practices.

Part 2: Content, behaviors, and research-based strategies

The strategies identified in chapter 2 that address content include implementing culturally relevant curriculum, developing cultural literacy, identifying funds of knowledge, enacting challenging curriculum, and using inquiry based methods. Those that address behaviors and relationships with students include identifying funds of knowledge, believing students are educable, introducing classroom mentors and role models, and promoting career education. In this part I will discuss each of the themes identified in the findings of chapter 4 by comparing enacted strategies with the ideals advocated in the literature.

Content-oriented strategies

Interviews and observations reveal that teachers used some of the strategies advocated for teaching science equitably including enacting challenging curriculum and using inquiry based methods. However, they didn't implement culturally relevant curriculum or identify funds of knowledge. Their failure to enact all four strategies for teaching content may be explained by their previous experiences in science, their limited understanding of "Science for all Americans", their beliefs about science and their concerns about preparing students for high-stakes tests.

Prior experiences in science

Surprisingly, none of the teachers remembered very much about their high school science experiences beyond a few hands-on experiences. For the most part, these experiences were very traditional in following a transmission model of learning. Teacher 5 describes an exception to this pattern: recall that teacher 5 remembered liking science in high school because he got to do a lot of fieldwork. However, he did not use fieldwork as one of his teaching methods. Although all of these teachers are teaching high school science, their prior science experiences do not provide models for them to emulate. Consequently, none of the teachers discussed nor were observed incorporating students' culture into the curriculum in the manner advocated in chapter 2.

Implementing culturally relevant curriculum, developing cultural literacy, and using funds of knowledge as the foundation for curriculum development do not appear to link directly to the goal of increasing participation in science based careers. Since the current knowledge base and practice of science is not situated relative to the home culture of many of their students, the home culture may appear irrelevant to teaching science. What teachers do not seem to understand is that the power in connecting students' culture and the study of science lies in the ability to engage students in learning the knowledge base of science situated in referents with which they are familiar and which employ their strengths and the funds of knowledge they bring to the classroom. Culturally situated science should increase positive attitudes about science, a critical indicator for pursuing science electives, which is one pathway to majoring in science in college, prerequisite for a science based career, by demonstrating to students how knowledge about science is relevant to their everyday lives and addresses problems and issues that they care about it, such as how a sick relative could be cured. Additionally, as students develop more positive attitudes about science, it is likely their engagement and subsequent achievement in science will also increase, the other critical indicator in the pathway to participation in science.

Several of the teachers had participated in the practice of science (1, 3, 6, 8) and could therefore have served as role models in encouraging their students in pursuing science based careers. However, teacher 1 was the only who frequently discussed his experiences with his students. Ironically, he was also the one who repeatedly mentioned that he didn't view preparing future scientists as one of his roles. These teachers missed the opportunity to enact the strategies identified in chapter 2 of introducing role models (themselves) and promoting career education (by sharing their professional experiences). However, their experiences as scientists probably contributed to the importance they attached to teaching content, a concern aligned with the strategy of enacting challenging curriculum.

Interpretation of "Science for all Americans"

The phrase "Science for all Americans" was unfamiliar to the participants so it was not surprising their interpretation of this phrase was limited and underdeveloped. Several of them mentioned that one aspect of this phrase is connecting science to the everyday world. This idea would be congruent with the concept of culturally relevant pedagogy and cultural literacy if the direction of this connection began with students' worlds and involved teaching concepts of science through students' home cultures. Unfortunately, because of teachers' demonstrated lack of attention to basing content on the home culture, it is unlikely that this is what teachers meant. Another aspect of this phrase teachers mentioned was development of critical thinking skills that would help students in the future. This sentiment aligns with the strategy of using inquiry-based methods since critical thinking is an indispensable aspect of successful inquiry. Likewise, given that critical thinking is an essential characteristic for successful practice of science, developing it is also congruent with the notion of equity embraced by this research. Another aspect of “Science for all Americans” teachers mentioned is giving all students equal access to learning science, a sentiment aligned with promoting equal participation in science based careers. Finally, teacher 8 mentioned giving students equal access to equipment. Although not a sufficient indication of equity, students who are not familiar with experimentation would be at a disadvantage in college level science courses relative to the average student.

External pressures on content

Teachers’ prior experiences with science may explain their monolithic view of content. Since none of them have experiences with culturally relevant curriculum, their notion of content is tied to the traditional referents through which they learned content. Additionally, since they teach principles of science that are well established, they may find less room for seeing alternative conceptions of the subject matter. Paradoxically, their views about the nature of science that might lead to culturally relevant teaching such as understanding that scientific knowledge is tentative and socially situated are not displayed in their practice. They present a positivistic view of curriculum in which there is one method for finding the right answer to any problem.

The atmosphere of institutional testing, such as the TAKS tests and district benchmark tests, implies that there is only one right answer to any science question, a condition diametrically opposed to the constructivist viewpoint and the tentative nature of science. Teacher 6 offered this insight as to why teachers may not enact culturally relevant curriculum when she observed, “It’s hard to enact ‘Science for all Americans’ when you have to work for biology for all Texans, as the TAKS (Texas Assessment of Knowledge and Skills) would mandate.” In other words, much of what teachers do in the classroom is tied to the IPGs or the TAKS tests. Since neither the IPGs nor the TAKS are connected to culture of students, it makes sense that teachers don’t think about teaching content through the vehicle of students’ cultures.

Although these external pressures appear to limit the enactment of strategies advocated in the literature regarding culturally relevant pedagogy, they serve to encourage teachers to enact curriculum that will prepare students for high achievement on standardized tests and success in future science courses.

The discretionary curriculum

As discussed in chapter 4, where motivated, teachers implemented curriculum solely of their own choosing. This finding allows for the possibility that if given training and motivation, teachers would be willing to enact the content-based strategies advocated in chapter 2.

Synthesis

The findings in this section offer evidence for why teachers' characterizations of their practice do not align with strategies related to culturally relevant curriculum identified in the literature for making science teaching more equitable: these strategies simply aren't in their teaching toolbox. They don't see content as a vehicle for motivating students to engage in science. Ironically, teacher 1 told his students about his experiences in working with high school students building houses. Through participation in the project, students came to understand principles of geometry, trigonometry, and algebra that they hadn't learned in their regular classes. In spite of his seeing the power of projects to motivate students to learn core concepts, teacher 1 didn't incorporate this idea in his pedagogy. Teacher 2 was the only one who saw learning of the content as a means to an end rather than an end in and of itself. Recall, he believes that as students develop a more scientific mind, they will learn the skills necessary to solve problems and gain control over their lives. Consequently, he views science learning as a part of the maturation process. Although teachers are concerned with teaching in a way that promotes development of content knowledge, they haven't yet begun to see their way to using science as a motivator and facilitator of science learning.

<u>Behavioral and relationship oriented strategies</u>

Interviews and observations reveal that teachers used some of the strategies advocated for teaching science equitably including inquiry. However, they didn't develop cultural literacy, identify funds of knowledge, promote career education, or believe their students were educable. To some extent, they introduced classroom mentors and role models and used "best practice" language strategies. Their failure to fully enact all six strategies for teaching content may be explained by their role identity, their means of assessing learning, and their deficit views of students.

Characterizations of teaching roles

My categorization of teachers into parents, role models, and institutional agents are consistent with teaching methods that would lead to the type of equity advocated in this research. Displaying the positive aspect of a parental orientation, teachers would do everything in their power to help students become self-sufficient adults, such as through pursuing one of the lucrative, science based careers. Teachers 1, 2, and 3 bring successful college science experiences to the teaching situation so they know how to mold students to enhance their chances for success in future science courses. Similarly, teachers 4 and 5 are role models in that they were successful in completing college even though their high school achievement wasn't high. Their presence in the classrooms may help students develop the idea that they can "make it" even if they haven't done so well up to this point. As institutional agents, teachers 6, 7, and 8 want to provide students with the learning they need to do well on traditional and standardized assessments, an achievement that is necessary in order to enter college. Furthermore, all the teachers want to transmit the knowledge base of their content area to students.

Although they don't characterize their roles this way, these teachers' practices are traditional in nature rather than inquiry-based as advocated in reform documents and the literature cited in chapter 2. While, the teachers include projects, hands-on experiences, and guided research in their teaching, all of these activities are very teacher directed. These teachers use methods consistent with a constructivist view of knowledge to teach concepts from the dominant science culture using activities that are teacher centered. Using constructivist methods to teach concepts from the dominant science culture using activities that are centered or derived from the students' culture, experience, or background would be a more equitable strategy. One explanation for teachers' failure to use inquiry-based teaching more aligned with the definition of inquiry from the National Science Education Standards (National Research Council (NRC), 1996) may be a lack of teaching role models to follow.

The findings about teachers' metaphors for their roles may provide another explanation for failure to use inquiry-based methods. Teacher 2's explanation of "easy to understand and follow" aligned with his usual practice of giving clear explanations or leading learners to understanding through Socratic questioning. Teacher 3's metaphor was self-focused, seeing herself as a little boat on an ocean and viewing kids as resistant to looking at themselves from her point of view. Teacher 5's metaphor of a tree was likewise more self-focused; it seemed consistent with his view of himself as a role model. Although teacher 5 showed care and concern for his students, there was definitely an aspect of one-sidedness in his never articulating that he learned from his students or saw things to admire in them. Teacher 8's description of himself as a sponge, absorbing information to share with students matched his classroom practice and responses: he exhibited the "teaching as transmission of knowledge" paradigm. A careful reader will note that other than teacher 4, none of these teachers articulate the type of role consistent with inquiry-based teaching, such as something that connotes a facilitator of learning.

Teacher 4's metaphor as a gardener seemed the most equitable and could also be consistent with inquiry-based teaching. She acknowledged that she didn't plant the seeds in the garden but was only tending for a short time. Her metaphor implied a two-way responsiveness to her students when she talked about attention to the right nutrients so that their roots would sink deeper and their leaves didn't turn yellow. Additionally, the seeds are already there as self-defining objects, perhaps implying the idea of prior knowledge. The gardener doesn't change the identity of the seeds but rather assists in the development of what they already are.

Assessing content knowledge

Developing cultural literacy is linked with equitable assessments. Assessment highlights aspects of the curriculum that the teacher values and wants students to know. Culturally literate teachers who assess the knowledge and skills, which are of value to the community, teach children the importance of developing cultural competence.

All of the teachers mention they assess student learning both formally and informally. However, in general, only traditional assessments such as tests, quizzes, worksheets, and other written work comprise the grades. Teacher 6 does do projects, which she assesses using rubrics. However, these contribute only a small percentage toward course grades. Teacher 4 is the only one who gives an extended response about non-traditional assessment, but admits that she doesn't incorporate these informal evaluations into grades. As with other items mentioned in this discussion, teachers seem to have no model for assessment and evaluation using methods in alignment with culturally literacy about students' home cultures. In addition, it is questionable whether or not these would carry the same weight with the teachers as evidence students have learned as traditional assessments. Teacher 4 mentions that the thing she values most, students talking about what they have learned, is not valued by the district or state. However, using traditional assessments aligns with the definition of equity given in chapter 1. In college, students will likely be measured using traditional assessments; acquaintance with how to successfully prepare for this type of assessment will enhance their chances for success in a science based career.

Deficit model teaching

A deficit model of students (Valencia, 1997) is diametrically opposed to the belief that students are educable and limits teachers' propensities to enact challenging curriculum. All of the teachers discussed the low reading and/or math skills that students bring to the classroom. Teachers 2, 5, and 6 also talked about how the lack of motivation of some of the students disrupts the learning of other students. Teachers' response to their perception of students' skills and motivation is to give remedial instruction, give students more time to complete assignments, give students the opportunity to redo poorly done work, give encouragement, and organize the learning environment. This one dimensional, negative view of students may be due to lack of cultural literacy. For example, are teachers accurately characterizing low motivation or are they misinterpreting student behavior? Bransford et al. (National Research Council (NRC), 2000a) describe problems that may arise when child-adult conversational patterns of a teacher's culture differs from that of his or her students. He or she may incorrectly label a student as unwilling to participate when the pattern of a student's response is different than expected.

Another problem with a deficit view of students is that it clouds what students bring with them. For example, many of the teachers in this study noted that half the students at the school would drop out between 9th and 12th grades. They fail to articulate that they are working with the 50% who choose to stay in school. The teachers don't see anything in the persistence of students who stay as a value worth capitalizing on (Ladson-Billings, 2001), a thought pattern that would be consistent with implementing culturally relevant curriculum, such as through the funds of knowledge approach.

A third problem with the deficit view of students concerns their future. Teacher 4 is the only one who articulates the possibility of socioeconomic mobility. Teacher 1 reiterates the view that most of his students will not go to college. However, he does try to relate class activities and topics with things that scientists do. He is the only one who volunteered the perspective that some of his students may go into science. When prompted, teacher 6 identified two students that she thought might continue on in science. No one else expressed the belief that science teaching would lead some of his or her students to major in science. The other teachers state that students will most likely end-up in lower middle class-type jobs such as mechanics, plumbers, and secretaries, if they have jobs at all.

All of these findings put into question whether or not teachers really do believe their students are educable. Many of the teachers stated outright that they intentionally reduce the difficulty of their courses because of their low expectations for their students. However, they maintain they still teach what students need to know in order to do well on local and statewide tests. As teachers reduce the difficulty of their courses, they are putting students' future chances for success in science in jeopardy. Thus, changing teachers' ideas about students' abilities becomes imperative in order to meet the goal of increasing participation in science. Since secondary teachers are agents for preparing students for success in science in college, they must believe students can understand this challenging curriculum in order to enact it.

The teachers mentioned the low reading abilities of their students. For example, teacher 6 talked about how difficult it was for students to try to acquire the language of biology on the shaky foundation of a fourth grade reading level. Teacher 6 mentioned that her way of addressing the reading problem was to use smaller words. As mentioned previously, none of the teachers saw science as a way to engage students in school, thereby giving them motivation and a vehicle for increasing their language abilities. Interestingly, teacher 8 talked about communication through computers as the most important way science knowledge advances in the current era. However, he did not incorporate this aspect of the nature of science into his instruction. For example, the plethora of Web-based data collection projects linking high schools and scientists could have formed a natural pathway for increasing students' language abilities in the process of embracing this aspect of the nature of science but were unutilized by teacher 8.

One explanation for their failure to see content as a way to increase reading and math skills may rise from a lack of reflection about the nature of teaching and learning. Teacher 2 is the only one who directly articulates the power of education to positively transform lives. Similarly, teacher 4 implies this same belief in her choice of metaphor and the way she talks about her students. Another explanation might be that the only evidence they consider when evaluating their teaching are test scores. Teacher 2 is the only one who gives examples of positive changes in student behavior as a direct result of teaching behaviors. Additionally, many of them divorce themselves from responsibility for students' achievement, citing previous preparation or family as barriers to significant to be overcome.

Operational caring

The findings of this section revealed teachers' attentiveness to students' futures, awareness of similarities between their life situations and those of their students, desire to build relationships with their students, and knowledge of students' emotional states. However, these findings were generally not incorporated in teachers' enactment of the curriculum but rather through informal channels such as one-on-one conversations. Attentiveness to students' futures could form a foundation for content. Unfortunately in this incidence, the knowledge teacher 1 had about students' futures, which didn't involve college, would probably act to decrease the type of equity called for in this paper. The awareness of similarities of life situations led teachers 4 and 5 to view themselves as role models, but the notion of role model didn't transfer into obvious content choices. Building relationships with students may provide teachers with the type of information necessary to enact culturally relevant pedagogy such as through the funds of knowledge approach.

Juxtaposition of beliefs about content and behaviors

As portrayed in figure 4.2, the teachers in this study enact high-level curriculum and have formed deep relationships with their students that lead to equitable behaviors such as providing a structured environment for learning and acting as role models. In addition, they are very familiar with the life situations of their students. However, what prevents them from enacting culturally relevant curriculum is their inability to build a link between their knowledge of students and their beliefs about content. So, even as they try to enact curriculum that will promote the learning of science, they are limited in their ability to fully engage students in science, promote positive attitudes about science, and subsequently widen the pipeline to science based careers for their students. Figure 5.1 offers a pictorial representation of the juxtaposition of content and teaching behaviors, including some familiar teaching methods, where appropriate. The shaded portion of the figure represents methods that would lead to the type of equity envisioned in this research, increasing parity between underrepresented groups.

Figure 5.1: Content, behaviors, and teaching methods

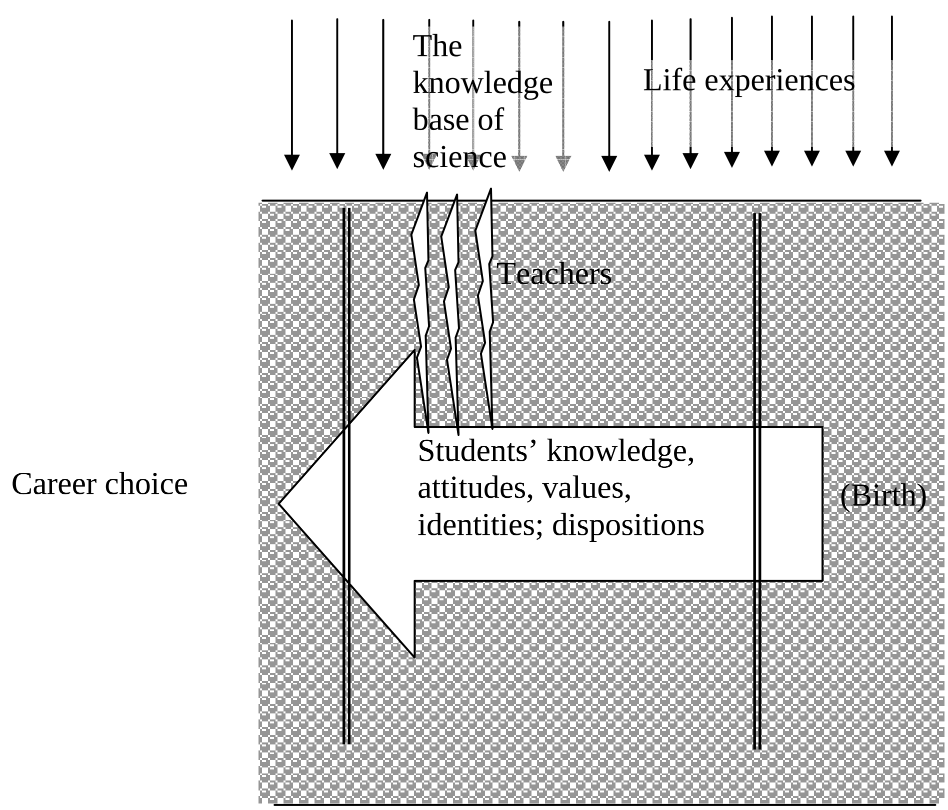
CONTENT	High-level & engaging		Inquiry based	Culturally relevant
	High-level	Traditional	Traditional	
	Low-level	Deficit model		
		Alienating	Culture generic	Culture specific
		BEHAVIORS & RELATIONSHIPS WITH STUDENTS		

<u>Aquifer model of equitable teaching</u>

The body of scientific knowledge, attitudes, processes, and mindsets (meteoric water) formally merges with student knowledge, attitudes, and mindsets (groundwater) through the mediation of teachers (aquifer). In an ideal classroom, the "teacher as aquifer" would be transformed by the groundwater, dissolving and enriching the flowing groundwater with minerals and oxygen as well as absorbing minerals or contaminants from the groundwater. This transformed "teacher as aquifer" would act on the formal curriculum flowing down as meteoric water from the surface, naturally modifying the nature of this incoming water in response to changes made to the aquifer by the flowing groundwater. Since the teacher acts as the mediator between groundwater and meteoric water, the waters not only merge but also mix. Metaphorically, students would acquire formal scientific knowledge in the classroom, even as the teacher acquires scientific knowledge from the culture of the students. As they move onto pursue careers in science, the unique characteristics these students bring with them from their wellsprings (cultural origins) transform the nature, practice, and body of scientific knowledge accepted by practicing scientists.

Sadly, the teachers of this study mostly act like fissures in the aquifer (See Figure 5.2). In other words, both meteoric and ground water flow through the aquifer in such a manner as to cause little change to any of them. Although the meteoric

Figure 5.2: Teachers' model of aquifer



waters merge with the groundwater in the classroom, instead of the thorough mixing that would occur if the water were flowing through tiny channels in the medium, the teachers act like fissures and there is little means through which mixing can occur. Instead the water merges without truly mixing. The aquifer gets wet, but there is no chemical and little physical change in the nature of the aquifer: teachers are aware of the needs, skills, origins, life experiences, motivation level, performance, and engagement of students in the classroom, but not the contributions they might bring to the science classroom and do little to intentionally cause material change in either the students, the formal curriculum, or themselves. Instead, they transmit the formal curriculum of the bureaucracy, which is contained in textbooks, the IPGs or assessed on the TAKS, with little modification.

Part 3: Implications and future work

These findings show a misalignment between equitable practices advocated by university-based researchers and the rhetoric and behavior of classroom teachers. This misalignment could be addressed through effective professional development programs that account for what teachers bring to the classroom. In other words, teacher professional development needs to be learner centered, identifying teachers as the learners, and attuned to the prior knowledge that learners bring to the educational situation.

Ending the discussion of this study at this point might satisfy many multicultural researchers. However, as a teacher educator, I think it is important to refocus attention to teachers as learners. One of the tenets of multicultural education is validation of students and the funds of knowledge they bring to the learning situation. Rather than using these findings to reinforce a deficit view of teachers I think it is essential to acknowledge and value what teachers bring to the classroom in order to design and implement professional development programs that build on these characteristics, enabling teachers to construct bridges between their practices and desirable student outcomes.

These teachers have built relationships with students to the extent that they know very private information about both students and their families. Additionally, teachers spend a lot of time teaching science content so that their students will do well on standardized tests. What they need from professional development programs are ways to incorporate students' experiences into the science curriculum that will also lead to high achievement on district and state exams. Note that such model programs specific to secondary science are scarce in the literature on culturally relevant education, especially models which provide evidence that they also meet the goal of achieving content mastery that will be required of them in the science pipeline.

These teachers are aware of the skill level and prior knowledge that students bring to the classroom. They are attuned to their students and characterize students' motivational levels. They know that facility with the English language will enhance students' ability to learn. They use this knowledge to modify their teaching to account for these characterizations of students. This awareness of students' skills and a willingness to accommodate learner characteristics in their pedagogy is a great strength they bring to the classroom. What they need from professional development programs are strategies for using the science curriculum as a way to build language and math skills and increase motivation while maintaining high expectations for student achievement.

These teachers exhibit strong content knowledge. Many of them have experiences as scientists that have led to a contemporary understanding of the nature of science. This understanding is an asset when considering how science could be both tied to the physical world and socially situated at the same time. What teachers need from professional development programs are models for using science content and knowledge about the nature of science to create culturally sensitive curriculum that also teach the currently accepted body of scientific knowledge tested on district and state science tests.

What teachers need from professional development are models for how to enact equitable teaching in the secondary science classroom.

The findings of this research suggest several future studies:

1. Identifying and characterizing successful secondary science teachers of culturally diverse students
2. Identifying models of effective culturally relevant pedagogy in the secondary science classroom
3. Methods for discovering and incorporating students' funds of knowledge into the secondary science curriculum.

APPENDIX A: Views on the Nature of Science (VNOS)

(Lederman et al., 2002)

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. What is an experiment?
3. Does the development of scientific knowledge **require** experiments?
   - o If yes, explain why. Give an example to defend your position.
   - o If no, explain why. Give an example to defend your position.
4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?
5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   - o If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - o If you believe that scientific theories do change:

Explain why theories change.

Explain why we bother to learn scientific theories. Defend your answer with examples.

7. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
    - o If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
    - o If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.
8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of event that caused extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction.

   How are these **different conclusions** possible if scientists in both groups have access to and **use the same set of data** to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.
- If you believe that science is universal, explain why and how. Defend your answer with examples.

APPENDIX B: Example of developing clusters from raw data

Coding of question 4 from the VOICE data:

<u>Step 1</u>

As described in chapter 3, the first step in data analysis was to identify relevant statements. However, as described in chapter 4, the purpose of this section of data analysis was to characterize teachers' responses to a single question, what four things they wanted students to walk away from their course with. Consequently, the four responses of each teacher comprised the data set for this sub-analysis. These responses are listed below:

The ability to formulate questions

The ability to acquire data to answer to their questions

The ability to evaluate information presented to them in terms of validity, accuracy, biases, etc.

A willingness, and an ability, to make decisions based upon information and data they have acquired and evaluated

Personal growth—hopefully they will experience some things that will make them a better, well-rounded person

Respect for self/environment

Better understanding of content

The feeling that they can be successful

Critical thinking. And I don't know, at their age, and with the time I have with them, I don't know how much I can foster that but that's very important

Basic understanding of genetics and evolution

The big ideas of biology, you know, that things change over time. I would like them to see the importance in the interrelationships of organisms, you know, an appreciation of the natural world. You know, they walk on the plants, and they'll knock things over, and they don't see that that's a problem. I would very much like for them to be able to come out of it with an appreciation that each thing has a place and a role to perform

A love, being excited about science; I would really love it if they walked out of my class, and think, "I would like to learn more about biology."

Respect for science

Locating key concepts among information

Discern logical and illogical thinking

Limitations of science

A sense of why science is important to us all

How to work together to solve problem

A better citizen

Last but not least, hopefully get enough science to get them through TAKS

Integrity

Service

Speaking kindly of others

Discovery and exploration of the world

The ability to analyze problems logically

An insight into the workings of Western Scientific thought

Some basic fundamentals of how chemistry works

An awareness that ongoing scientific progress will impact their lives

Science is relevant to their lives

Science is an important source of technological advances that make life more comfortable

I understand myself better because of what I've learned in biology

Science has rekindled or piqued my curiosity about the world and how things work

Step 2

The next step in the analysis involved grouping identified statements into themes, based on similarity of underlying concepts. 13 categories were generated from the data along with a brief description of the underlying concept

1: Scientific mental processes

The ability to formulate questions

The ability to acquire data to answer to their questions

The ability to evaluate information presented to them in terms of validity, accuracy, biases, etc.

A willingness, and an ability, to make decisions based upon information and data they have acquired and evaluated

Critical thinking. And I don't know, at their age, and with the time I have with them, I don't know how much I can foster that but that's very important

Discern logical and illogical thinking

The ability to analyze problems logically

Discovery and exploration of the world

2: Aspects of personal growth

Personal growth—hopefully they will experience some things that will make them a better, well-rounded person

How to work together to solve problem

Integrity

Speaking kindly of others

3: Attitude or value

Respect for self/environment

4: Content knowledge

Better understanding of content

Basic understanding of genetics and evolution

The big ideas of biology, you know, that things change over time. I would like them to see the importance in the interrelationships of organisms, you know, an appreciation of the natural world. You know, they walk on the plants, and they'll knock things over, and they don't see that that's a problem. I would very much like for them to be able to come out of it with an appreciation that each thing has a place and a role to perform

Last but not least, hopefully get enough science to get them through TAKS

Some basic fundamentals of how chemistry work

5:Self efficacy

The feeling that they can be successful

6: Positive attitude about science

A love, being excited about science; I would really love it if they walked out of my class, and think, "I would like to learn more about biology."

7: Respect

Respect for science

8: Learning skill

Locating key concepts among information

9: Understanding about nature of science

Limitations of science

10: Sociological goals

Service

A better citizen

11: Understanding of a specific science

An insight into the workings of Western Scientific thought

12: Relationship between student and science

A sense of why science is important to us all

An awareness that ongoing scientific progress will impact their lives

Science is relevant to their lives

Science is an important source of technological advances that make life more comfortable

I understand myself better because of what I've learned in biology

13: Science-based knowledge of the world

Science has rekindled or piqued my curiosity about the world and how things work

Step 3

Clusters based on shared meanings were generated from the themes. Four clusters were identified along with a description of the shared meanings.

Cluster A was formed from groups 1, 9, and 11. These statements reflect processes, mindsets, and propensities common for the practice of science by scientists, including an understanding of the nature of science.

The ability to formulate questions

The ability to acquire data to answer to their questions

The ability to evaluate information presented to them in terms of validity, accuracy, biases, etc.

A willingness, and an ability, to make decisions based upon information and data they have acquired and evaluated

Critical thinking. And I don't know, at their age, and with the time I have with them, I don't know how much I can foster that but that's very important

Discern logical and illogical thinking

The ability to analyze problems logically

Discovery and exploration of the world

Limitations of science

An insight into the workings of Western Scientific thought

Cluster B was formed from groups 2, 3, 8, and 14. These statements reflect items of personal attributes such as attitudes, values, potential, and life skills.

Personal growth—hopefully they will experience some things that will make them a better, well-rounded person

Locating key concepts among information

How to work together to solve problem

Integrity

Service

A better citizen

Speaking kindly of others

Respect for self/environment

The feeling that they can be successful

Cluster C was formed from group 4. These statements reflect a concern for developing science content knowledge or scientific knowledge about the world.

Better understanding of content

Basic understanding of genetics and evolution

The big ideas of biology, you know, that things change over time. I would like them to see the importance in the interrelationships of organisms, you know, an appreciation of the natural world. You know, they walk on the plants, and they'll knock things over, and they don't see that that's a problem. I would very much like for them to be able to come out of it with an appreciation that each thing has a place and a role to perform

Last but not least, hopefully get enough science to get them through TAKS

Some basic fundamentals of how chemistry works

Cluster D was formed from groups 6, 7, 12, and 13. These statements reflect developing an appreciation for science and scientific activity.

A love, being excited about science; I would really love it if they walked out of my class, and think, “I would like to learn more about biology.”

Respect for science

A sense of why science is important to us all

An awareness that ongoing scientific progress will impact their lives

Science is relevant to their lives

Science is an important source of technological advances that make life more comfortable

I understand myself better because of what I’ve learned in biology

Science has rekindled or piqued my curiosity about the world and how things work

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